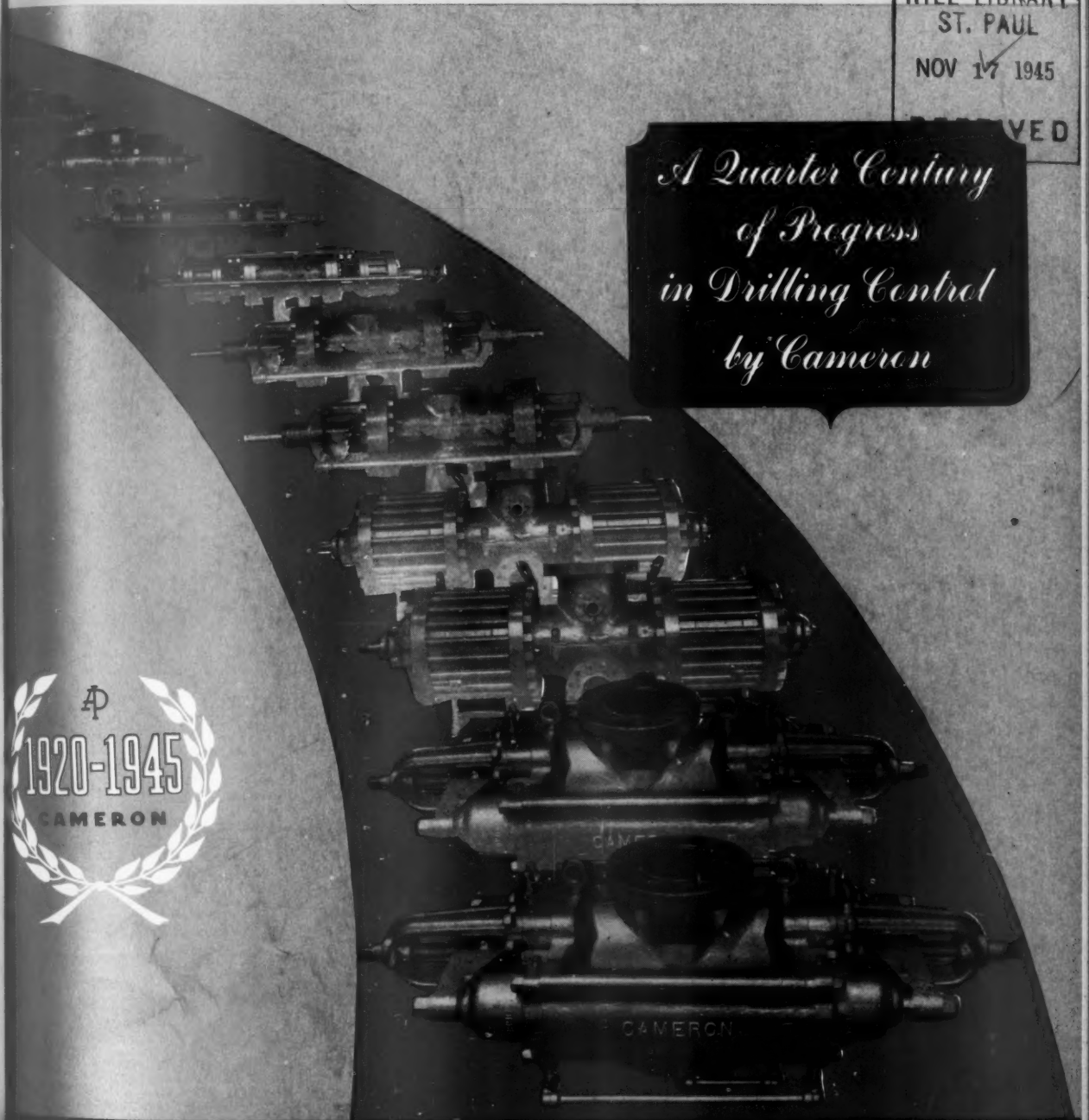
the OIL AND GAS JOURNAL

HILL LIBRARY
ST. PAUL
NOV 17 1945
VED



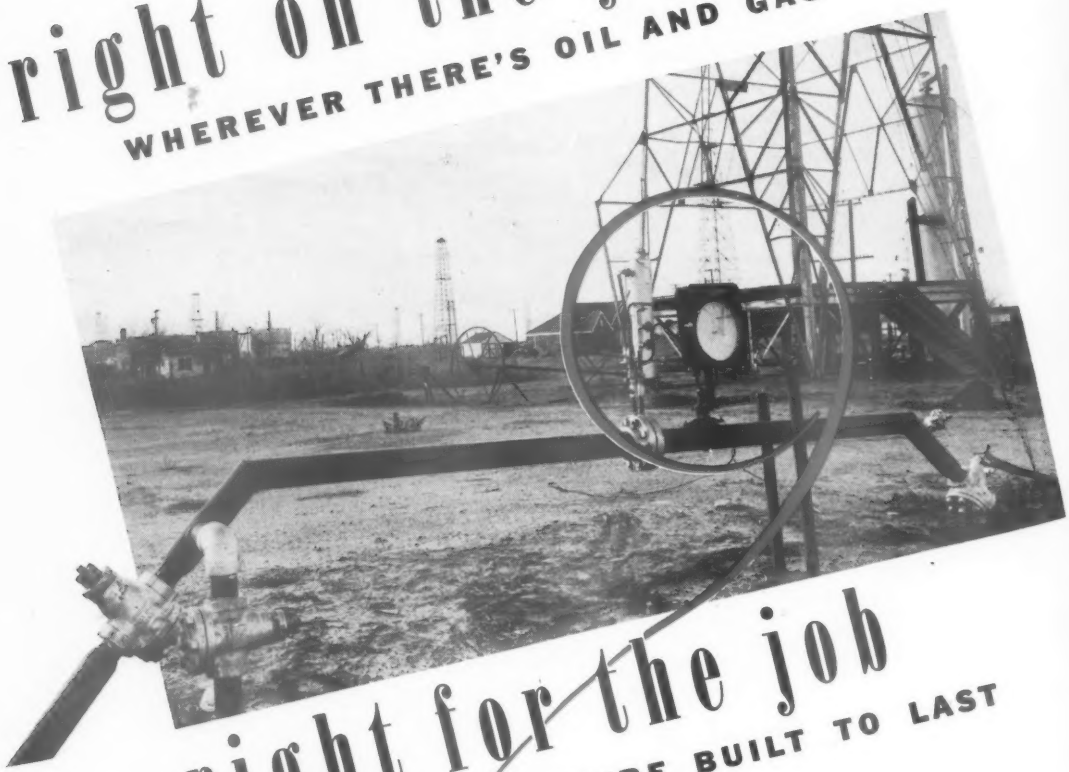
AMERON IRON WORKS, INC. HOUSTON, TEXAS

PRICE 20 CENTS A.P.I. NUMBER NOVEMBER 17, 1945

XUM

right on the job

WHEREVER THERE'S OIL AND GAS



right for the job

BECAUSE THEY'RE BUILT TO LAST

EMCO-McGaughy Integrator
mechanically computes orifice meter charts with speed and accuracy

EMCO ORIFICE Meters

PITTSBURGH EQUITABLE METER COMPANY

Atlanta, Pittsburgh, Houston, Tulsa, Kansas City, Los Angeles, Seattle, San Francisco, Boston, Chicago, New York

MERCO NORDSTROM VALVE COMPANY
Main Offices, PITTSBURGH, PA.

National Meter Division, Brooklyn, N. Y.

the OIL AND GAS JOURNAL

published weekly by the

PETROLEUM PUBLISHING COMPANY

211 S. CHEYENNE AVE., TULSA 1, OKLAHOMA

Subscription rate to the petroleum industry, United States and foreign, 1 year, $3.00. Single copies, 20 cents. Back copies, when over a year old, 50 cents. Entered as second-class mail matter at Tulsa, Okla., under Act of March 3, 1879. Copyright 1945, by The Petroleum Publishing Co.

Vol. 44, No. 28 November 17, 1945

P. C. LAUINGER, *President* — C. O. WILLSON, *Editor*

S. H. ROURKE, *Business Manager* — H. STANLEY NORMAN, *Managing Editor*

R. C. MAC DOUGALL, *Circulation Manager* — ARCH L. FOSTER, *Refining Editor*

W. L. NELSON, *Technical Editor* — PAUL REED, *Pipe-Line Editor*

Associate Editors

LYNN M. NICHOLS — NEIL WILLIAMS

CHARLES J. DEEGAN — KENNETH B. BARNES

R. B. TUTTLE

District Editors

JAMES McINTYRE, Tulsa 1, 211 S. Cheyenne Ave. — THOMAS F. SMILEY, Tulsa 1, 211 S. Cheyenne Ave.

TOLBERT R. INGRAM, Denver 2, State Office Bldg. — E. H. SHORT, JR., Houston 2, Sterling Bldg.

HENRY D. RALPH, Washington 4, Natl. Press Bldg. — L. P. STOCKMAN, Los Angeles 14, Union Oil Bldg.

FABIAN R. STALEY, New York 17, 415 Lexington — O. C. PRESSPRICH, Saginaw, News Bldg.

VICTOR LAURISTON, Chatham, Ont., 35 Stanley Ave.

Advertising

E. KLAPPENBACH, *Vice President*

KENNETH J. LANGLEY, *Eastern Manager*, New York 17, 415 Lexington Ave. — CHARLES A. WARDLEY, *Pittsburgh Manager*, Pittsburgh 19, Grant Bldg.

C. R. FARMER, *Chicago Manager*, Chicago 2, 185 W. Madison — J. HOWARD TINKHAM, *California Manager*, Los Angeles 15, 1406 S. Grand Ave.

WAYNE RIVES, *Gulf Coast Manager*, Houston 2, Sterling Bldg. — A. J. CHAMBERS, Beckenham, Kent, England, 33, The Avenue

MITCHELL TUCKER, *Manager, Research Dept.*, Tulsa 1, 211 S. Cheyenne Ave. — JOHN D. REILLY, *Production Manager*, Tulsa 1, 211 S. Cheyenne Ave.

Member
Audit Bureau of Circulations
Associated Business Papers

Table of Contents

NEWS DEVELOPMENTS

Ickes Urges Recognition of National Interest in Petroleum 152
Boyd Pledges Ability of Industry to Continue Forward Progress 152
Industry Told of Need for Improved Public Relations 153
Authorization Given for Formation of National Petroleum Council 153
Well-Spacing Important But Not Only Factor in Maximum Recovery 154
Senate Committee Expected to Hold Hearings on Oil Pact 156
Texans Brand Pact as Violation of Sovereign State Rights 156
Plans for "Mother Hubbard" Suit Indefinite, Officials Say 157
German Patents to Be Returned to Standard 157
Wartime Refining Equipment Needs Alteration for Peacetime Use 158
90,000-Bbl. Haifa Refinery Largest in Mediterranean Area 160
Pacific Section A.A.P.G. and Allied Groups Meet in Los Angeles 166
Secondary-Recovery Research Progress Is Chronicled 167
Deaths in the Industry 168

Trends 151
This Week 155
Editorial 159
Natural-Gas News 297
Pipe-Line News 301
Refining News 304

A.P.I. SECTION

Petroleum War Team 169
Oil's War Record: Plenty, When and Where Needed 172
The Battle for 100-Octane Production 172
The Battle of Supply and Transportation 173
The Battle for Crude Oil 174
The Battle for Materials 175
Petroleum Industry War Council—Personnel 176
Staff of Petroleum Administration for War 179
Pressure Maintenance by Water Injection, Midway Field 185
Injection of Water Into Underground Reservoirs in Michigan 193
Behavior of Water-Input Wells 205
Interactions Between Interstitial and Injected Water—A Review 219
Petroleum vs. Plutonium 227

ENGINEERING AND OPERATING

Central Electric Power Plant Solves Pumping Problem at Gilbertown 275
The Optimum Rate of Production—Part 12 279
Questions on Technology 284
Practical Petroleum Engineering—No. 5 286
Plant Practices 289
Unitized Equipment for Pipe-Line Gathering Service 290
The Refiner's Notebook 293
Engineering Fundamentals 295

DRILLING AND EXPLORATION

Week's Highlights 307
Weekly Well-Completion Record 307
Daily Average Production for Week 308
Reports by Areas Start on Page 308

ADDITIONAL FEATURES

Drilling Contractors 322
Events on the Calendar 323
Personals 324
Men in Equipment News 326
Classified Advertising 327
Market Summary 329
Crude-Oil Prices 329
Advertisers' Index 330

POLYMERIZATION

CONVERSION RECONVERSION

DURING THE WAR many polymerization plants were converted to supply cumene and codimer for the air forces.

Now that peace is here these plants can easily be reconverted to again produce civilian gasoline. In addition equipment from processes not readily adapted to civilian use may be converted to polymerization.

Universal Oil Products Co.
Chicago 4, Ill., U. S. A.

UOP

Petroleum Process Pioneers
For All Refiners

U. O. P. Service Protects Your Refinery

the OIL AND GAS JOURNAL

Trends

Crude-Oil Production
By States—Page 308

CRUDE-OIL STOCKS 221,031,000 bbl. as of Nov. 3—down 3,199,000 bbl. One year ago 222,894,000 bbl.

GASOLINE STOCKS 76,421,000 bbl. as of Nov. 3—up 2,086,000 bbl. One year ago 78,054,000 bbl.

RESIDUAL FUEL-OIL STOCKS 46,128,000 bbl. as of Nov. 3—up 185,000 bbl. One year ago 63,526,000 bbl.

GAS OIL AND DISTILLATE STOCKS 44,487,000 bbl. as of Nov. 3—up 1,015,000 bbl. One year ago 47,329,000 bbl.

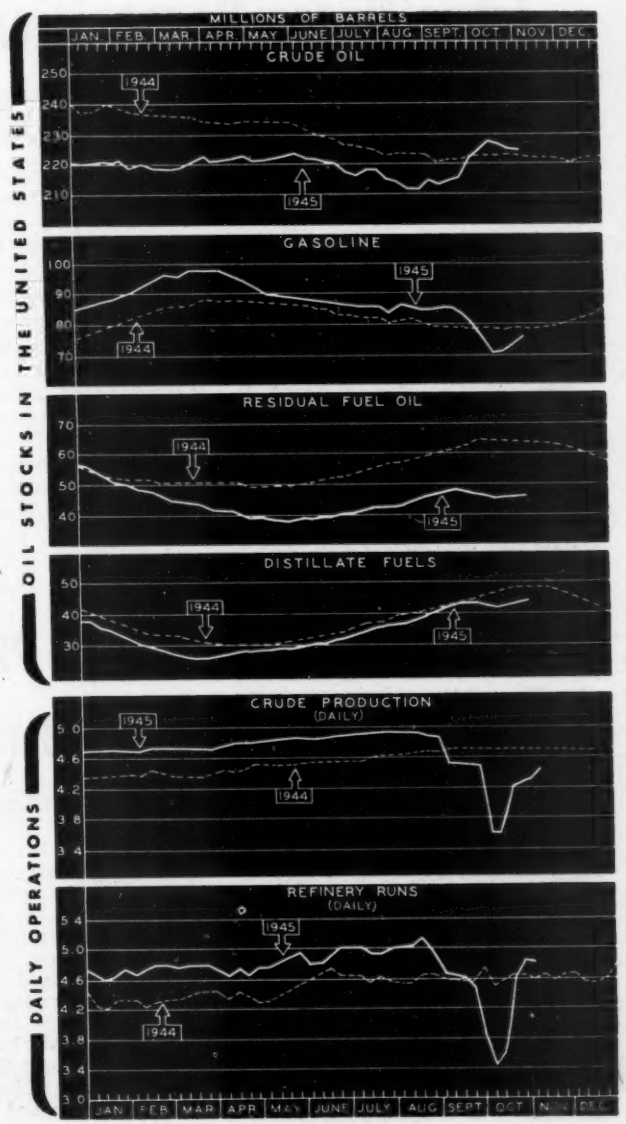
CRUDE-OIL PRODUCTION 4,459,150 bbl. as of Nov 10—up 145,200 bbl. One year ago 4,731,850 bbl.

REFINERY RUNS 4,807,000 bbl. daily week ended Nov. 3—down 31,000 bbl. One year ago 4,602,000 bbl

SIGNIFICANT potentialities of plutonium as a source of energy were pointed out this week at the American Petroleum Institute meeting in Chicago. In one of the most profound discussions of atomic power and its relationship to petroleum and coal yet presented publicly, it was estimated that at least a generation will pass before any widespread change will come about. A suggestion of the power derivable from plutonium, an end product of nuclear fission between uranium and graphite, is afforded by the fact that burning of a pound of the material produces heat equivalent to that resulting from combustion of a ton of petroleum.

FROM a long-range viewpoint, the most important potential impact of atomic energy on the petroleum industry is the possibility that the nature of this business will be changed radically in years to come. In fact, it was suggested that hydrocarbons in petroleum might be used to a better advantage as the source material for lubricants, plastics, and medicinal substances. If the potentialities of plutonium were developed for maximum commercial utilization, it is evident that the petroleum-refining industry would swing more completely to the chemical field. The possibilities for consuming petroleum in the alternative fields of commerce are so extensive, it was pointed out, that producers, transporters, and manufacturers have little to fear from competitive fuels. The only change imaginable—and this is years ahead—would be a swing to products which currently are only in the laboratory stage or at best in extremely limited volume.

INABILITY of scientists and technicians to make more rapid use of plutonium as a source of power for conventional commercial and domestic requirements result from the weight of shielding materials required for safe handling. Ocean liners and battleships, for example, would lose all advantage of the greater unit power in plutonium because of the added weight necessary to confine the nuclear energy. The same limiting factor applies to use of plutonium in automobiles and other mobile equipment. On the other hand, it is conceivable that plutonium may replace petroleum or coal at some of the larger power plants within the relatively near future because mobility is not required and shielding requirements would be simplified.



Among speakers at the general sessions of the A.P.I. were Capt. B. W. Gillespie, executive officer, Navy Petroleum Plant Office, Washington; Dr. Virgil Jordan, president, National Industrial Conference Board, New York; Vice Adm. Ben Moreell, chief of the Bureau of Yards and Docks and officer in charge of Navy Petroleum Plant Office, Washington, and Dr. Paul H. Giddens, curator of Drake Well Memorial Park and Museum, Titusville, Pa.

Ickes Urges Recognition of National Interest In Petroleum in Addressing A.P.I.

CHICAGO.—A plea for recognition of a national interest in petroleum was voiced here this week before the A.P.I. annual meeting by Harold L. Ickes, petroleum administrator for war and secretary of the interior. He spoke Wednesday afternoon before a general meeting of the Institute.

Administrator Ickes hastened to add that he does not mean "nationalization" or "government competition" or "government domination" in asking for a common understanding of the problem. He said that Government and industry need to make certain that this nation will always have access, at home or abroad, to all oil it may ever require.

Much of Ickes' address was devoted to explaining various sections of the Anglo-American agreement which he said was designed to assure "that there will be no more hobbling of American nationals" in foreign operations with such devices as the red line agreement.

He attempted to allay any remaining fears that the Anglo-American oil commission would have regulatory powers of any sort. He pointed out that the agreement stipulates that the commission can only make reports and studies of world petroleum supply and requirements. It will be up to the individual units in the industry to make intelligent use of the commission's facts.

Three broad objectives were proposed by Ickes as the nucleus for a national oil policy which he declared was badly needed. He suggested (1) do all that we can to stimulate the exploration for oil in the United States; (2) use efficiently the oil that we may have so that it may last as long as possible by eliminating waste; (3) assure ourselves of access to foreign oil resources so that they may supplement our domestic supplies if they are needed.

Ickes said that he enjoyed a stirring sense of pride in the knowledge that covenants made with leaders of the oil industry in order to meet exigencies of war emergency had been scrupulously observed. He commended the industry for the task it performed during the war, often proceeding without reasonable assurance of compensation for the extraordinary expenditures required.

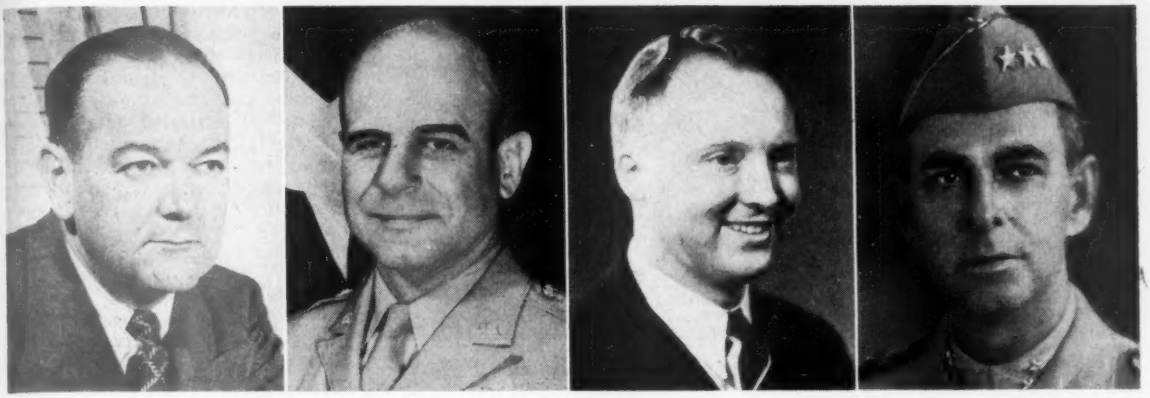
Highlights of proceedings and several of the technical papers presented at the twenty-fifth annual meeting and Victory Jubilee of American Petroleum Institute are presented here and in a special section beginning on page 169. The Journal's editorial staff is represented at Chicago by C. O. Willson, H. Stanley Norman, Arch L. Foster, and Charles J. Deegan, with O. B. Irizarry representing the Journal's affiliated publication, Petroleo Interamericano. Additional technical papers delivered at the meeting will be published in next week's issue.

Boyd Pledges Ability of Industry To Continue Forward Progress

CHICAGO.—William R. Boyd, Jr., president of American Petroleum Institute, in his presidential address at the Victory and 25th Anniversary annual meeting of the Institute, recounted the growth of the institute with the industry, and recognizing the rapid changes due in the future, pledged that the institute, with cooperation from its members, would meet the problems of the future, and work for the preservation of a framework of free enterprise, within which to achieve a still higher standard of living.

Speaking to a large audience, he stated, in part:

"As a result of the tremendous impetus given technical progress during the war, we can foresee even greater changes ahead. No one knows today what the final results will be, but we know from experience that the scientific 'know how' of the petroleum industry will meet whatever requirements may be asked. The growing chemical nature of the petroleum industry, as yet little understood by the public, deserves careful consideration. I have



Other speakers at the general sessions of the A.P.I. were C. R. Smith, board chairman, American Airlines, Inc., New York; Lt. Gen. James H. Doolittle, U. S. A. A. C., Washington; Dr. Clark Goodman, Massachusetts Institute of Technology, Boston, and Lt. Gen. Raymond S. McLain, U. S. A., Washington

said on numerous occasions that the science of hydrocarbon chemistry contains the seeds of many new industries. We will make good in these new lines of endeavor because this industry has learned cooperation.

"The success of American industry has been based upon two things; first, the willingness of Americans to venture and the absence of legislation forbidding them to do so; and, second, the development of skills. No industry exemplifies that statement better than petroleum. The pioneers of the petroleum industry ventured into a field of which they knew little. They used hunches for geology; their drilling methods and equipment were hit-or-miss; their refining practice was crude and their market was variable and uncertain. Yet, because they were willing to venture, this great industry came into being, grew and developed.

"Whenever a welter of regulations destoys the producer's hope of profit, he will not, and in justice cannot, risk his capital or that of others. While the effect upon the small producer is more immediate, in the long run that fact applies to every producer of oil, regardless of size.

"Victory is ours. The war has been won. We helped and helped mightily. The measure of our help was increased by our unity of purpose and effort. Petroleum Administrator Ickes and Deputy Administrator Davies have in all respects kept faith with the industry.

"But now as we turn to peaceful pursuits and operations, let us remember that the peace has not been won. Reconstruction, world reconstruction must take place. In the process of change, may the petroleum industry make its constructive contribution toward readjustment in the same united intelligent way in which it made its magnificent contribution to the destructive processes of war."

Industry Told of Need for Improved Public Relations

CHICAGO. — Suggestions for improving the public relations of the petroleum industry were discussed in a symposium here today at the 25th annual meeting of American Petroleum Institute. Three public relations consultants set forth in a general open session the principles and techniques by which the industry can "tell its story" to the American public.

Glenn Griswold, New York, editor of Public Relations News and Planning for Business, said the oil industry is not maintaining public contact as are other industries and petroleum should give new attention to winning public confidence and recognition.

J. Robert York, Chicago, western manager of American Newspaper Publishers Association, presented a slide talk illustrating the effective arguments that can be marshaled, and the way these arguments can be presented to support the cause of free enterprise in the oil industry.

Theodore R. Sills, Chicago, president of Sills, Inc., and vice president of National Association of Public Relations Counsel, stressed the new methods of reaching the public by concrete reference to labor-management problems. He urged an enlightened and fair treatment by industry of its side of public issues as a necessity in competing with labor organizations and other groups in the "war of words."

The discussions pointed up the problem of an expanded public relations service now being studied by the institute, and on which program action is expected by the institute's board of directors later this week.

Authorization Given for Formation Of National Petroleum Council

CHICAGO. — Authorization was given here November 12 to an oil industry committee headed by W. Alton Jones, president of Cities Service Co., for a detailed study of the organization and functions of a national petroleum council. The Jones committee is functioning under authorization of Petroleum Industry War Council which will be dissolved after its next meeting December 11.

The national council currently under consideration would become the peacetime counterpart of PIWC and would deal, according to preliminary thinking, with the broad general problems of the oil industry. The new council, if it is finally authorized, would be composed of the present members of PIWC. Former members of PIWC would become associate members of the new group.

A subcommittee will be appointed

XUM

A. F. van EVERDINGEN

S. E. BUCKLEY

W. W. VIETTI

R. P. CRAZE

W. B. BERWALD

O. F. THORNTON

These engineers were among those participating in a symposium discussion on well spacing at the meeting of the production division

by Jones within a few days to study all aspects of the proposed National Petroleum Council. Legal aspects of the council will receive particular study in order to make certain that participants do not risk prosecution for violation of antitrust laws. The national council, as conceived by its sponsors, would be supported by contributions from individual members and would be independent of any government bureau or agency.

Membership in the council would be perpetuated on the same basis as PIWC with presidents of trade associations automatically seated and their predecessors becoming associates.

Well Spacing Important But Not Only Factor in Maximum Recovery

CHICAGO.—Well spacing is only one of many factors that are important in obtaining maximum recovery from oil reservoirs. Furthermore, for most types of reservoirs, many engineers are of the opinion that variations in spacing, wide or close, have only a small effect, often no effect at all, on the amount of oil recovered from any given reservoir.

This group of engineers appears to be gaining in numbers and influence. They stress that attention of other conditions in the reservoir and to production rates and techniques are generally of much greater importance than well spacing in influencing the amount of oil ultimately recovered from any given reservoir.

In general they tend to regard well spacing for any given reservoir as mainly a matter of economics and for that reason believe that wide spacing is generally the most profitable when considering the economics of the reservoir as a unit.

These conclusions seem obvious as a result of the attendance and comments at the group session of the division of production at A.P.I. meeting here. The group session was held under the auspices of the special study committee on allocation of production and well spacing, which is a branch of the central committee on production practices.

The committee was careful, however, to point out that it has taken no official stand on the question. This function to date has been to sponsor and encourage the collection of all pertinent data on many oil fields throughout the United States, and to encourage authors to prepare and present papers, in which the conclusions and recommendations are the sole responsibility of the authors, and not an official commitment of the committee or the Institute.

The committee believes that by a continuation of this type of work and continual addition of factual data, progress can be made toward the solution of the general problem of determining the real importance of well spacing and its effect on ultimate production.

Three papers were presented at the group session on Wednesday morning. "Optimum Well Spacing," was presented by W. H. Barlow and W. B. Berwald of the Ohio Oil Co. "A Factual Analysis of the Effect of Well Spacing on Oil Recovery," was presented by R. C. Craze and S. E. Buckley, of Humble Oil & Refining Co. "The Relation Between Well Spacing and Recovery," was presented by W. W. Vietti and O. F. Thornton, The Texas Co., J. J. Mulane, The Carter Oil Co., and A. F. Van Everdingen, Shell Oil Co., Inc.

In general the engineers are in agreement that methods are now available which permit reliable estimates and predictions of the behavior of an oil or gas reservoir throughout its productive life. From data that can be obtained after completion of the first well in a new pool, it is often possible to calculate the probable recovery from the reservoir under many assumed future operating conditions.

Such calculations, even though largely theoretical, enable the engineer to determine from the known and assumed economics involved in the development of the reservoir, how many wells should be drilled to obtain the greatest recovery from the reservoir as a whole, with the least total cost. The number of acres per well, determined in this manner, is the optimum spacing for the reservoir.

The engineers pointed out, however, that well spacing is not a simple engineering problem. No two pools are identical and many factors are variable within a pool, and of course the maximum amount of clearly understandable data is not available until late in the development period, or even late in the ultimate productive life of the pool. However, the possible variations in recovery from any given reservoir resulting from variations in engi-

(Continued on page 158)

THIS WEEK

HEAT—Texans bitterly denounce revised oil treaty. . . . State Land Commissioner Giles: "Masterpiece of collusion between certain officials of Great Britain and United States." . . . Chairman Culberson, State Railroad Commission: Exempts chief oil holdings of Britain while "subjecting all oil resources of this country to international control and manipulation." . . . Wording declared tampered with. . . . ¶But Ralph Zook, former president I.P.A.A., says: "Has none of the ambiguities of previous agreement." . . . Ickes says it assures "no more hobbling of American nationals." . . . PIWC urges ratification. . . .

LITIGATION—Mass of technical testimony features suit against Humble and Texas, charging patent infringement in use of phosphates in treatment of drilling muds. . . . Trial may consume several weeks. . . . ¶Justice Department officials say no plans made for immediate prosecution of "Mother Hubbard" antitrust suits against A.P.I. and 21 major oil companies, though way now is clear. . . . Insist no intention of dropping case. . . . Hanging fire during 5 war years. . . . ¶Federal Court orders return to Jersey Standard of patents bought before 1939 from I. G. Farbenindustrie and seized by alien property custodian. . . . Cost company $35,000,000. . . .

A.P.I.—Industry's eyes turn to Chicago. . . . Ickes tells Institute national interest in petroleum should be recognized. . . . Doesn't mean nationalization, government competition, or government domination. . . . Just common understanding. . . . ¶President Boyd says industry prepared to inaugurate intensive search for new reserves. . . . ¶Glenn Griswold thinks industry should give fresh attention to gaining public's confidence. . . . ¶E. V. Murphree says wartime fluid catalytic-cracking units were overdesigned. . . . Modifications now necessary. . . . ¶Others add to fund of technical knowledge. . . .

PRODUCTION—Continuing its rise for fourth successive week, daily crude-oil output averaged 4,459,150 bbl., up 145,200. . . . Texas contributed 104,200 bbl. of the increase, all districts helping except Panhandle which lost 4,000. . . . Oklahoma responded to increased allowable for West Edmond wells by registering rise of 27,350 bbl. . . . ¶Week's completions 528, down 27. . . . ¶Stripper-well subsidies totaled $49,822,347 in 9 months beginning August 1944. . . . ¶Navy plans to continue development of Alaskan petroleum reserves, under civilian contract. . . . Navy personnel to be used on geological phases only.

LABOR—President Knight, Oil Workers Union, declares Truman responsible for strikebreaking activities unless he sets up machinery for adjusting wage disputes. . . . ¶President Jennings, Socony-Vacuum, says wage increases granted by company and rejected by minority of union employes, exceed standard proposed by Truman. . . . ¶Stabilization Director Collet hopes to develop formula for selective price increases to absorb wage increases. . . . Directive expected soon. . . .

REFINING—Big Misberg refinery, Germany, wrecked by bombing, restored to production by two oil-wise Allied officers in 3 weeks. . . . Job had been expected to consume 6 months. . . . ¶Nazi liquid-fuel research secrets uncovered by Allied investigators to be analyzed and distributed to American industry by Bureau of Mines. . . . ¶John Suman predicts gasoline demand may rise so that nation's light-crude resources will have to be devoted to motor and aviation fuels. . . . Deficit in fuel oils to be met by imports. . . .

An 18-ft. gasoline hose on a self-winding reel makes it unnecessary for the motorist to jockey for position at Shell Oil Co.'s "Service Station of Tomorrow," unveiled in New York November 10. Now a memory is the world's first drive-in station, shown here as it looked when opened for business in St. Louis in 1895. But it was little short of epochal, with its gravity tank on stilts, a faucet, and 15 ft. of garden hose. Before that they had retailed gasoline in cans at paint and hardware stores

XUM

Senate Committee Expected to Hold Hearings on Oil Pact

by Henry D. Ralph

WASHINGTON. — Senate foreign relations committee is expected to decide soon on the procedure to be followed in submitting the Anglo-American oil treaty to the Senate for ratification. It is probable that hearings will be scheduled, but they may not be held till after the Christmas recess.

Because of the few protests received so far it has been suggested that the committee might well submit the treaty to the Senate without hearings, but this procedure is unlikely in view of the insistent demand for full hearings when the first draft of the treaty was submitted last year. Officials of the State and Interior departments are prepared to appear at hearings and give a full explanation of the purposes and operation of the agreement, and it is probable that oil men who assisted in the revision will want to explain the differences between the original and the present draft.

The chief objections to the treaty made so far appear to be based on the section defining the areas of the British Empire. One word was changed in this section between the time the text was released to the press in London and the actual signature, but officials who participated in the drafting insist that this change makes no difference whatsoever.

In defining the word "country" as applied to the United Kingdom, the treaty as submitted to the Senate says it includes "those British colonies, overseas territories, protectorates, protected states, and all mandated territories administered by the Government." The original release read "all British colonies, etc."

Appended to the treaty was a list of United States and British overseas territories considered as part of each country. Some objection has been raised because this list does not include certain areas where British oil companies operate, particularly in the Persian Gulf area. Such objections appear to overlook the fact that to include such countries in the list would be tantamount to declaring them a part of the British Empire without their consent, which, in addition to serious diplomatic complications, would have the effect of making them part of England's "domestic" area—similar to the relationship between Hawaii and the United States—as regards the international oil trade.

Texans Brand Oil Pact as Violation Of Sovereign State Rights

AUSTIN. — Sharp criticism of the revised Anglo-American oil treaty is voiced by leaders of the petroleum industry in Texas and by men high in government circles of the state. "Masterpiece of collusion," "trap," and "death blow to the rights of a sovereign state" are among terms employed in commenting on the instrument.

"Ratification of the treaty could lead to the development of a gigantic camouflaged international cartel, the very kind which flourished under the rule of fascism and nazism," declared Bascom Giles, state land commissioner.

"It will not only amend the Constitution through subterfuge but will deal a death blow to the rights of a sovereign state to regulate production of one of its greatest sources of wealth.

"There is also no doubt but that recognition of this pact would cost Texas millions of dollars in school land revenue annually. Government control under the Petroleum for War Administration, supplementing state control, tolerated during the national emergency, was dictatorial and cumbersome enough, but for this Government sublimely to ignore state rights and pass over sweeping control to a foreign political hierarchy during peacetime would be catastrophic.

"Such action would be tantamount to permitting peaceful subjugation by foreign powers, who in ravaging our national resources, would soon drag us down to the economic level of a second-rate power or to political and economic serfdom."

The hidden danger of the treaty, Giles said, lies in the fact that no provision is made to prevent representatives of probable additional signatory powers, producing only a fraction of the world's oil supply, from entering into a collusion to outvote this nation in matters of control production and marketing.

"Texas," continued the commissioner, "would be harder hit than any other state in the nation since it would have little to say about where private business could drill. Neither could it regulate production to prevent draining away this great wealth for the benefit of some foreign power. There would be no such thing as state control, as such policy making would depend on the whims of members of the proposed international council who could exercise supreme dictatorial power over exploration, production, and marketing.

"Everyone familiar with methods often employed to foist harmful legislation on the public, has recognized the old trick of dressing a wolf in sheep's clothing and slipping it in. There can be no doubt but that once adherents of the pact succeed in securing its passage the next step would be to restore the fangs."

Culberson Demands Rejection

Olin Culberson, chairman of the Texas Railroad Commission, called for "emphatic rejection" of the pact. The text of the agreement as filed with the Senate, Culberson asserted, contained an unannounced change of one word which had the effect of exempting the chief oil holdings of Britain from its provisions while "subjecting all the oil resources of this country to international control and manipulation."

The agreement, declared Culberson, has become a "trap" for this country's oil industry. Substitution of "those" for "all" between the time the text was released for publication and the time of its submission to the Senate, had injected a wholly different meaning.

According to Culberson, the wording as originally published stipulated that all British colonies and all American territories were to be included in the agreement in the exchange list. He referred particularly to the reported omission of Burma and Kuwait, rich oil fields on the Persian Gulf, from the British list accompanying the treaty.

Typical of opposition among independent oil operators is a statement issued by D. W. Hovey, Houston. Hovey says "necessity for the original Anglo-American oil treaty . . . and proposed new agreement has never been publicly disclosed or proven."

XUM

Plans for "Mother Hubbard" Suit Indefinite, Officials Say

WASHINGTON. — Department of Justice spokesmen do not admit that official plans have been made for immediate prosecution of the long-pending "Mother Hubbard" suit against American Petroleum Institute and 21 major oil companies in spite of the fact that there are now no apparent obstacles to further proceedings.

The 5-year-old case was postponed during the war under an agreement with the federal court in the District of Columbia whereby the Justice Department may at any time ask the court to restore the case to its calendar and give the defendants at least 60 days to file answers to the bill of complaint. Many other antitrust cases similarly postponed because of the war have been revived since hostilities ended, and some of them have been settled.

Political pressure is being brought on the department to revive the A.P.I. case now that war controls over petroleum marketing and transportation have been dropped. Department officials admit that they have enough attorneys on the staff to try the case, that their files are up to date, and that the District Court's calendar is not too crowded for early action. They also concede that there is no cause for delay in the current labor.

One possible explanation is that attorneys for the defendants are negotiating with the department for entry of a consent decree, which would settle the case without trial. No confirmation of this conjecture has been obtained, but it is recalled that before the war there were negotiations for the consent decree which resulted in unofficial agreement on a majority of the matters involved in the suit.

It would not be illogical for the defendants to resume these negotiations where they were dropped, and since this is a purely civil suit, with no criminal charges, it is probable that the department would welcome settlement by a consent decree instead of going through with a trial.

At the same time department officials insist that there is no thought of dropping the case or letting it go by default. There has been some suggestion that an amended bill of complaint might be filed in order to bring the case up to date. Aside from technical changes, which could easily be made during trial of the case or in a consent decree, the only practical purpose of a new bill of complaint would be to include additional charges of antitrust violation or to ask the court for additional forms of penalty or relief. Speculation is that if the case is made tougher it will ask for pipeline divorcement, a subject which was considered when the case was worked up but which was not included in the complaint as filed.

German Patents To Be Returned to Standard

NEW YORK.—Return to Standard Oil Co. of New Jersey of all patents which the company bought from I.G. Farbenindustrie prior to 1939 and were seized by the alien property custodian, has been ordered by Federal Judge Charles E. Wyzanski in an opinion filed here with the U. S. District Court. Jersey Standard and three of its subsidiaries are entitled to the return of the patent rights for which the company paid $35,000,000, and which have been retained by the Government since their seizure in March 1942, under the Trading with the Enemy Act. The 92-page decision ruled that the Government may retain title only to those licenses and patents which the company obtained from the German chemical trust after the start in Europe of World War II.

The decision holds, however, that the alien property custodian may keep other patents and stocks acquired by Standard Oil from the German firm at a conference at The Hague in 1939 following the German attack on Poland. Under these patents Jersey Standard acquired processes for the manufacture of buna rubber, acetylene arc, and paraffin-oxidation processes. Patents ordered returned cover processes for manufacture of high-octane gasoline.

The right of the Government to seize and retain the patents was challenged in a trial which ended here last June.

Let Appalachian Area Use Its Own Fuel, Says Davis

NEW ORLEANS.—Louisiana sees no reason why it should be "pouring the enormous volume of our remaining supply of natural gas into states which have other fuels," Gov. Jimmie Davis told Federal Power Commission, which this week opened another regional hearing in a general investigation of the natural-gas industry.

Davis referred to Pennsylvania, West Virginia, Ohio, Alabama, Tennessee, "and other Appalachian states," as having "almost limitless reserves of coal." And "many of them also produce natural gas and petroleum," he added, contending that areas which have their own fuel sources should use them.

The Louisiana governor said he agreed with a report made by FPC in 1940, which condemned the use of natural gas for the production of steam-boiler heating, but that he believed exceptions might be made for states which have no other fuels.

Drilling-Mud Suit Attracts Technicians, Scientists

HOUSTON. — Technical men and scientists of the oil industry fill Federal Judge T. M. Kennerly's courtroom, where a suit alleging infringement of drilling-mud patents by Humble Oil & Refining Co. and The Texas Co. is being heard. The trial may consume 3 weeks.

The action, in which Truman B. Wayne, Houston inventor and patent holder; Visco Products Co., and National Lead Co. are plaintiffs, avers that the two oil concerns have infringed patents in the use of phosphates for controlling the density or viscosity of drilling mud.

William W. Robinson, chief chemist for The Texas Co. in California, and Everett B. Hays, Houston, petroleum engineer for the company, testified that their concerns, with one or two possible exceptions, had made no use of phosphates in drilling muds since the patent was issued a short time ago. Hays said that much of the clay in Gulf Coast wells makes "pretty good drilling mud without treatment."

Venezuelan Operations Are Normal, Following Revolt

Programs for drilling operations in Venezuela are proceeding normally since the recent revolt by which control of the government was seized by the Junta party, according to Gifford C. Parker, president, Parker Drilling Co. His own organization has five rigs drilling for Atlantic Refining Co. in Venezuela and is shipping a sixth rig there from Houston.

Airplane bombing and fighting at Caracas was observed by Parker from the roof of the Avila Hotel, who has commented that much of the violence and pillaging was by armed mobs which the government took steps to disarm after the coup d'etat had succeeded.

XUM

Well Spacing in Maximum Recovery

(Continued from page 154)

neering techniques applied, are often much less important in the economics of the reservoir as a unit than the cost of drilling the wells. This is particularly true of very deep reservoirs. Likewise the price of oil will sometimes have more economic effect than some of the variations in techniques applied.

For these reasons, as well as numerous others, the engineers say that any calculated optimum spacing for a new pool is only an approximation of the true optimum spacing. They simply do the best they can with the amount of information available early in the history of the pool. The more reservoir data that is available from the first well or the first few wells, the more closely the calculated optimum spacing is apt to approach the true optimum.

Buckley and Craze reported on an analysis of the estimated ultimate recovery from 97 oil fields in the United States, and said that well spacing seems to have little to do with the optimum recovery. They stressed that important factors in the ultimate recovery of these fields are the viscosity of the oil, the reservoir pressure declines, and the formation permeabilities.

Vietti and others reported that they had made a study of fields in Texas that were very similar in type and had come to the conclusion that no more oil was recovered from closely drilled reservoirs than from the reservoirs of the same type that had wider spacing. They recommended that well locations be based upon engineering principles, based upon the behavior of oils in the reservoir.

Wartime Refining Equipment Needs Alteration for Peacetime Use

CHICAGO. — Wartime fluid catalytic cracking units were overdesigned, to make allowance for corrosion, erosion, and other effects on the equipment, for which no experience was available to guide the designer, E. V. Murphree and his collaborators stated at the 1945 annual A.P.I. meeting here this week. Because experience has determined that these ill effects can be controlled within reasonable limits, these units now can be operated at increased capacities, Murphree said. To accomplish this result some changes and additions of equipment must be made to the original design, the most important of which is the installation of new air-compressor equipment; alterations to permit spent catalyst stripping; reinforcing catalyst recovery equipment; adding a preheat furnace, along with increase of the heat-exchanger and pumping facilities. The authors have estimated that the additional cost will amount to less than $100 per barrel of charge per day on the unit. This would amount to a maximum of $1,000,000 for a 10,000-bbl. unit.

The mechanical strength of the regenerator limits the pressures which can be used in fluid units, Murphree said. This limits the amounts of air which can be introduced to burn off carbon and regenerate the catalyst. Operation of a plant at 12.5 psig. air pressure increases the carbon-burning capacity by about 20 per cent above that attainable with air pressure of 5 lb., which is more than 70 per cent above the design value. Under the less-severe conditions of operation for making motor gasoline as compared to aviation-fuel manufacture, the 540,000 bbl. of fluid capacity can be boosted to 720,000 bbl. of throughput per day. The original plants built by Standard of New Jersey were designed for feed rates of 15,500 bbl. per day. By increasing the rate of air inlet from, say, 45,000 to 55,000 cu. ft. per minute the rate of carbon burning is raised by 30 per cent. The original estimate for making motor gasoline, 20,000 bbl. per day charge, can be exceeded, Murphree stated. By raising the regenerator pressure from 1.8 to 5.0 psig. and the temperature from 1,055° to 1,125° F., and the use of an improved stripper have made possible an increase of 43 per cent in carbon-burning capacity and, or from 13,110 to 18,800 lb. per hour. On the reactor side of the unit, use of the improved stripper and aided by a decrease in the catalyst-to-oil ratio reduced carbon yield from 6.4 to 5.4 per cent. The reactor temperature stayed practically constant because of the higher inlet temperature, the reactor gas velocity was held at a better level by increasing the pressure from 10 to 17.5 psig. and by a decrease in the amount of process steam. By these methods the feed capacity was increased from 16,400 to 28,000 bbl. per day. Yields of main products included 40.8 per cent of motor gasoline 49.9 per cent of cracked gasoline and polymer, the latter from the 8 per cent or more of butylenes, and 37 per cent of cycle oil. The clear octane rating of the motor fuel was 82 A.S.T.M. and gave 85.3 with 1.5 cc. of TEL. The C.F.R. research rating was 96.1 clear, and 99.3 with 1.5 cc. of TEL.

Catalyst-to-oil ratios need not be high to obtain the required gasoline production by the Thermofor catalytic cracking method, T. P. Simpson and S. C. Easterwood of Socony-Vacuum Oil Co., Inc., and H. G. Shimp, of Houdy Process Corp., stated. Catalyst-to-oil ratios of 1.8 to 4.0 are adequate to get the desired results. Overcracking may occur at higher catalyst-to-oil ratios, they stated, which produces a rapid increase in coke and gas yields and a consequent and corresponding loss in gasoline yield and useful vapor-recovery products. Charge stock should be below 4 per cent by weight in Conradson carbon residue to maintain the coke deposition at reasonable values. Heavy asphaltic stocks should be deasphalted before charging since they give excessive coke deposition. Deasphalted stocks reduce this coke deposition and give increased yields from the same unit.

War developments have increased greatly the research applied to fractionation, and have improved correspondingly the efficiency of refinery units, P. J. Harrington, B. L. Bragg, and C. O. Rhys, Jr., Standard Oil Development Co., stated in discussing fractionator equipment. Minor changes in the internal structure of prewar towers increased crude throughput from less than 30,000 to 40,000 and even to 50,000 bbl. per day with good efficiency, they stated. Light-ends fractionators were increased in capacity from 30,000 to 45,000 bbl. per day in separating isobutane and normal butane, with more than 100 per cent plate efficiency. Much of this result was obtained by clearing the vapor path by removal or reduction in size of items of equipment in the tower such as holddown bars, size, dimensions and clearances of plate caps, etc.

A summary of the investigations of the U. S. Government technical oil mission to Germany was given by W. C. Shroeder, U. S. Bureau of Mines. He stated that the German technologists produced many petroleum-like products by the Fischer-Tropsch synthesis and then processing the products in various ways. Synthetic wax made by this process was cracked and then polymerized to make good lubricating oils. Other oils were made by polymerization of ethylene gas and subsequent treatment. Still other oils were made by chlorinating Fischer-Tropsch middle fractions, and reacting with naphthalene and aluminum chloride as catalyst by the Friedel - Crafts reaction.

FOUNDED IN 1910

BY PATRICK C. BOYLE

The OIL AND GAS JOURNAL

Dollars and Sense

BRITISH discrimination against American petroleum equipment has become the most serious factor in delaying postwar rehabilitation throughout Europe and Asia. Furthermore, the tactics, sponsored by the British Government as a trade policy, are damaging a segment of American industry which can contribute most to world recovery, if the current impossible trade barriers are removed.

Orders are being canceled daily for American-made equipment intended for installation by British companies abroad or in sterling bloc countries. Duplicate orders are being placed with British manufacturers. With few exceptions the English factories are not in position to fill orders for 2 years or longer. In other cases, the British are seeking licensing arrangements with American equipment companies to use the latter's patents and know-how to produce specialties.

All these developments contribute to an exceedingly unhealthy situation in Anglo-American relations and are particularly trying to American petroleum-equipment manufacturers. Advancements in oil-field and refinery equipment through the years have been made almost exclusively by American manufacturers. The new specialties and improvements on standard items have resulted from costly and time-consuming research and development. To ask American concerns to retire from the export market which they have fostered through the years is incompatible with the friendly nation concept.

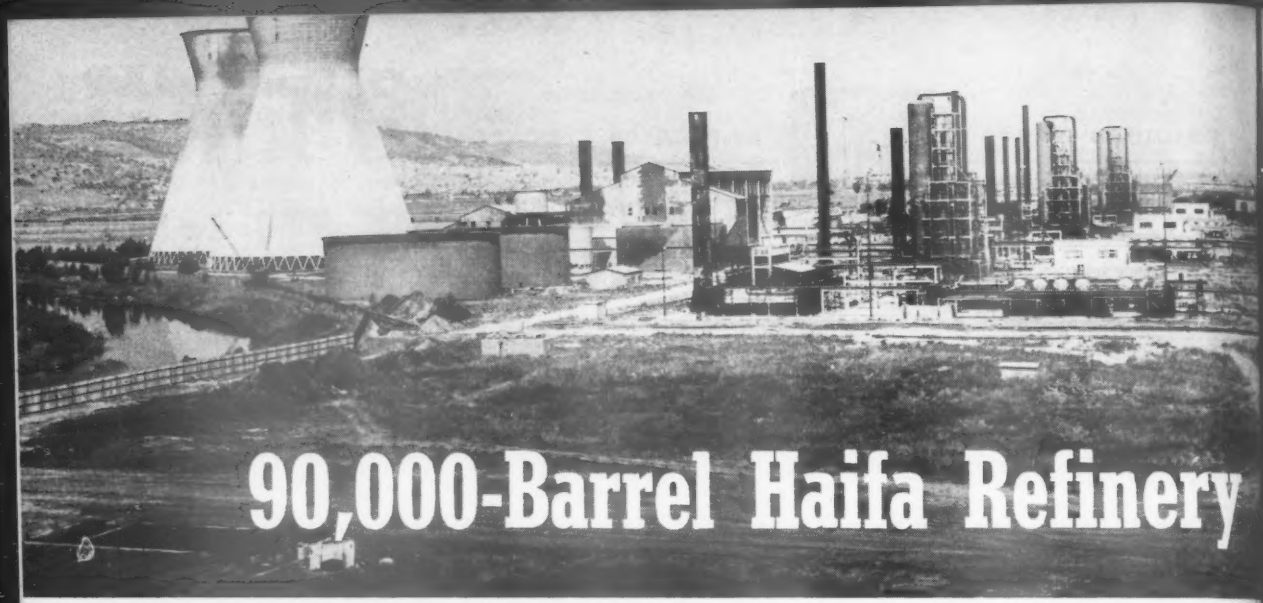
Assertions of the British that dollars are not available for purchase of equipment in this country are not entirely confirmable. Part of the doubt can be traced to current negotiations for a 5-billion-dollar loan to Great Britain. Exporters are clamoring for a complete disclosure of the British dollar position before the loan is concluded. The British are equally determined, it seems, to withhold information on the volume of dollars spent in sterling countries by American military forces. The impression is generally held that the British have more dollars now than they had at the start of the war. Nothing has been done to refute this opinion, and silence is interpreted as confirmation.

Delays in rehabilitating war-ravaged petroleum facilities in Europe and Asia are deplorable. Petroleum ranks with food as an essential in restoring the impoverished nations of Europe and Asia.

American oil companies operating in sterling countries or dependent on pound markets for product sales are helpless. Sterling income cannot be converted to dollars for purchase of American petroleum equipment so long as the present buy-British policy prevails. A specific example of how this works to delay restoration developed recently in plans of an American company to restore its terminal at Singapore. American manufacturers promised delivery within 6 months on the required tanks. British import control thwarted the plan, and the oil company was instructed to buy from an English manufacturer or abandon the program.

There is no assurance that any part of the uncontrolled 5-billion loan sought by the British will be applied to unfreezing dollar trade. A clear statement of policy on this point alone would be helpful. Meanwhile, it is unthinkable that the United States Government can give serious consideration to the British loan until these trade obstacles are removed.

XUM



90,000-Barrel Haifa Refinery

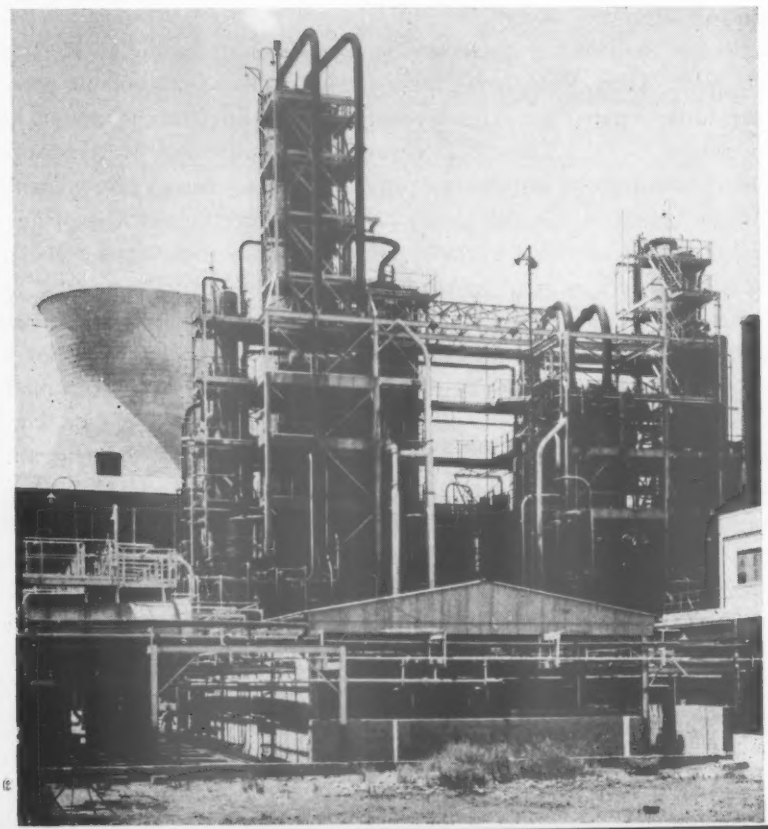
General view of Haifa, Palestine, refinery of Consolidated Refineries, Ltd.

MIDDLE EAST REPORT No. 9

by C. O. Willson

HAIFA, Palestine.—A refinery designed for peacetime operation, which was converted to a war plant with its original capacity doubled, summarizes the 6-year life of the 90,000-bbl. plant of Consolidated Refineries, Ltd., located here on an important port of the eastern Mediterranean. The operating company is jointly owned by Anglo-Iranian Oil Co., Ltd., and Anglo-Saxon Petroleum Co. (Shell) with A.I.O.C. in charge of plant management.

Construction work in the refinery started in 1938. It was originally planned for the refinery to process most of the 40,000 to 45,000 bbl. of crude oil which constituted the daily deliveries of Iraq Petroleum Co., Ltd., to Haifa, starting in 1934 when the line was completed. Each of the two owners of Consolidated Refineries, Ltd., has a 23¾ per cent interest in Iraq Petroleum Co., Ltd., one of the major producers and pipeline operators in the Middle East. The production of the Iraq company at present consists of 85,000 bbl. daily in the Kirkuk field of northern Iraq, half of which is delivered to Haifa and the other half to Tripoli, Lebanon, about 130 miles north of here. The crude oil is stabilized and the hydrogen sulfide removed in a 90,000-bbl. stabilization plant located in the Kirkuk field.



View of one of the combination topping and vacuum units at the Haifa, Palestine, refinery

Ownership

Compagnie Francaise de Petrol (which is owned by the French Government) and Near East Development Co. [Standard Oil Co. (New Jersey) and Socony-Vacuum Oil Co., Inc.] both have a 23¾ per cent interest in the Iraq company. Before the war most of the crude oil from the Haifa and Tripoli terminals was delivered to French refineries of affiliated companies, including the French company which has two refineries. Under the 1938 program the crude oil delivered to the Tripoli terminal was to continue to go to the

Largest in Mediterranean Area

French refineries while the Haifa crude oil was to be refined at the new plant.

The program included an arrangement by which the refinery would process part of Near East Development Co.'s share of the crude oil, with the products to be made available to Standard Oil Co. (New Jersey) and the Socony-Vacuum Oil Co., Inc., for distribution by the two companies in this area.

The first 29,000-bbl. unit consisted of crude-oil topping, wax cracking, and viscosity breaking of the residual product. A second unit of the same design and capacity was completed in 1941, the two units having sufficient capacity to refine all the crude oil available from the Haifa crude-oil deliveries. These units were built and all other major construction at the refinery was done by M. W. Kellogg Co. The reforming units, which were primarily designed to reform the heavy gasoline cut from the crude-oil topping operation, were built, but have never been operated. With this design the refinery was prepared to process a maximum yield of high-octane motor fuel, and of distillate-fuel blending stock.

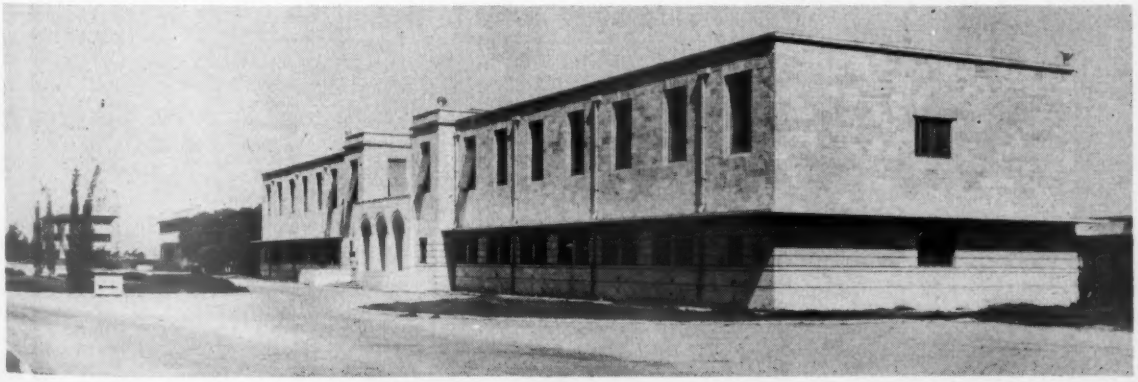
War-Brought Changes

The course of the war necessitated changes in the original design before the second combination unit was completed. The fall of France and the entry of Italy into the war on the side of Germany made the Haifa refinery the principal source of petroleum products in the Mediterranean area and the Allied war management decided that the plant should be operated to secure the maximum yield of liquid products.

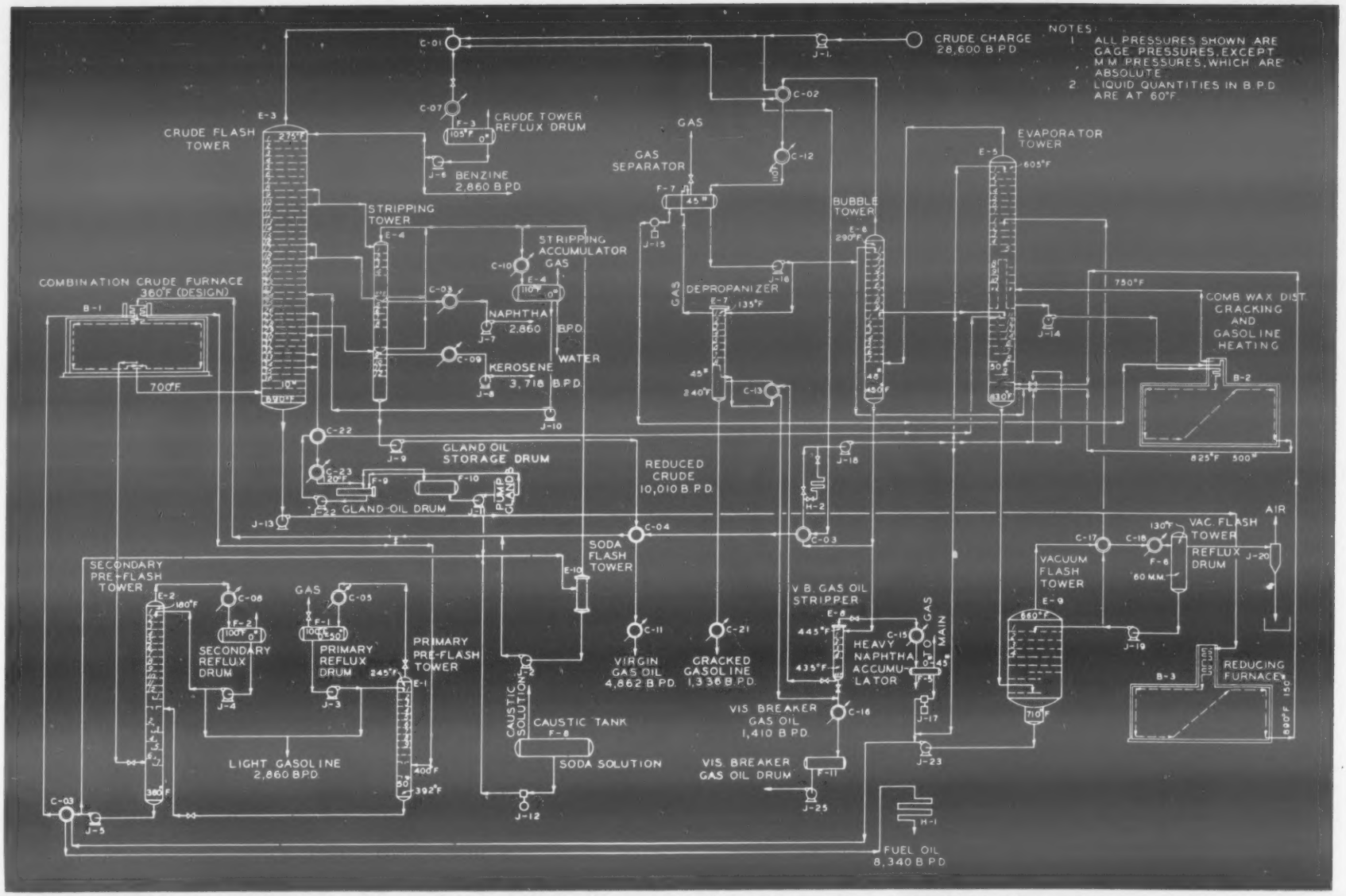
To that end changes were made in the operation of the combination units, in order to distill and fractionate additional crude oil. The wax-cracking operation was converted so that the heating and cracking capacity could be utilized in increasing the crude-oil charge. The viscosity-breaking phase of the combination operation was altered to produce an asphalt cut. A plant was installed to process solid and cut-back bitumens from the asphalt fraction. The company also operates a plant to manufacture drums and a drum-filling plant for the finished bitumens.

An interesting sidelight in this asphalt operation is that the building which houses the drum manufacturing plant was built for the SO_2 plant which was to be used to treat kerosene. The equipment to operate the plant was on its way to Haifa from Germany when the war started. The boat with the equipment never arrived.

With this type of war operation there is no place for the two 10,000-bbl. reforming units which were built to operate with the two combination units. The reformers would reduce the yield of finished products. To secure the octane rating for the gasoline, which would have been supplied with the reformers in operation, additional tetraethyl lead is used. The products at this time are 80-octane motor gasoline, special naphtha, kerosene, gas oil, diesel fuels, fuel oil, bitumen, and butane gas. These products are secured from the Kirkuk crude oil,

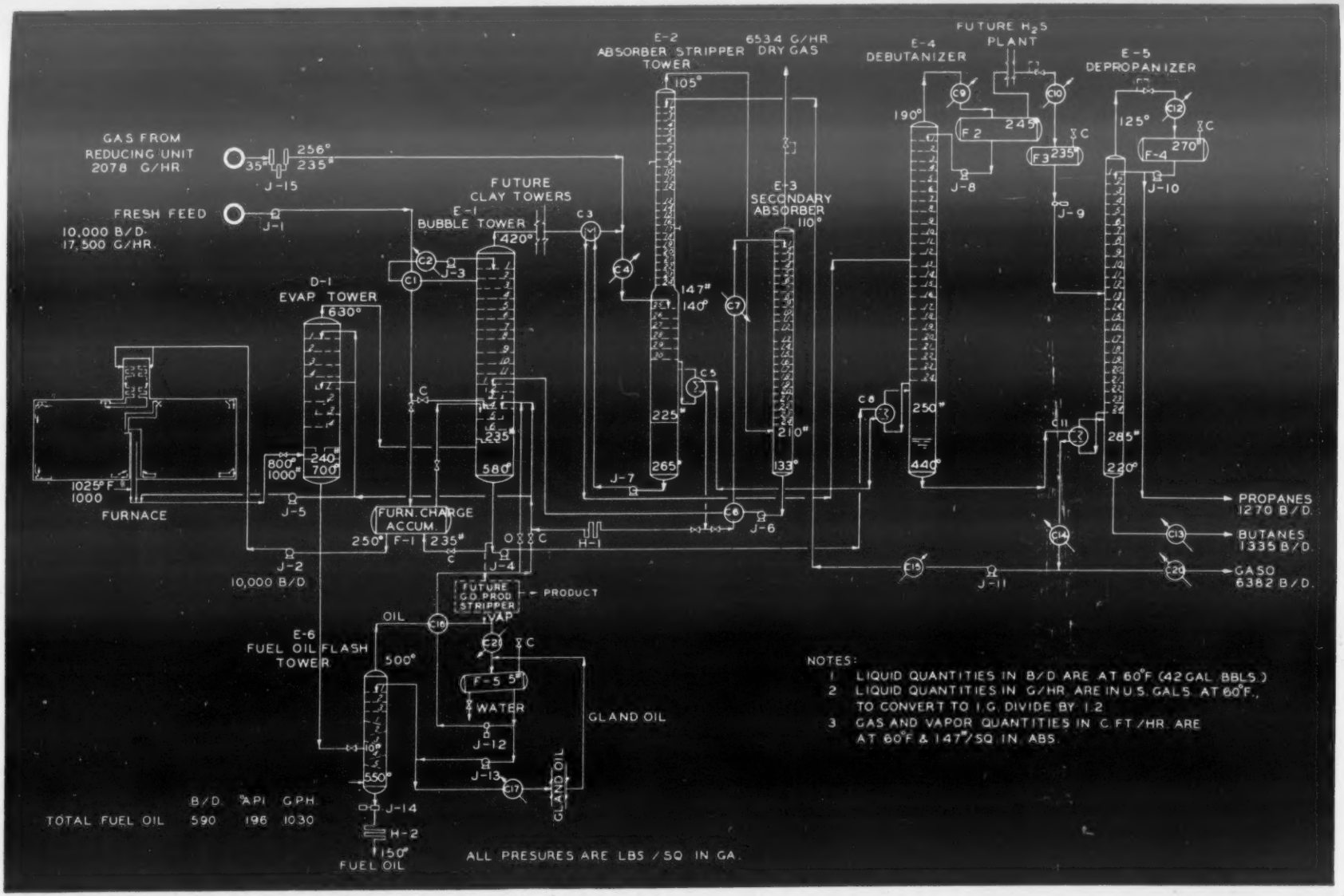


General office and administration building



Simplified flow diagram of crude-oil distillation units 1 and 2 at Haifa, Palestine, refinery of Consolidated Refineries, Ltd.

XUM



Simplified flow diagram of refining operation

a distillation test of which follows:

CRUDE-OIL DISTILLATION (A.S.T.M.) STABILIZED IRAQ CRUDE

	°C.	°F.
I.B.P.	45	113.0
2 per cent distilling to	57	134.6
5 per cent distilling to	71	159.8
10 per cent distilling to	96	204.8
20 per cent distilling to	140	270.0
30 per cent distilling to	187	354.6
40 per cent distilling to	235	441.0
50 per cent distilling to	287	534.6
60 per cent distilling to	340	630.0
70 per cent distilling to	400	738.0

To increase the capacity of the refinery so that it could refine all the pipe-line crude oil available from the operation of Iraq Petroleum Co., Ltd., a third 28,000-bbl. crude-oil distillation unit was completed in August 1944. This unit is the same in design as the topping side of the combination units. This installation increased the crude-oil capacity to 85,000-90,000 bbl. daily. The refinery now refines all but a small quantity of the crude oil produced by Iraq Petroleum Co., Ltd., with the crude oil delivered at the Tripoli terminal shipped to Haifa by a fleet of tankers.

Rerun Operation

To improve the lead response of the finished products the gasoline cuts are rerun in three steam-heated rerun units. These units, of Badger design, have both atmospheric and vacuum towers with a capacity of 10,000 bbl. each.

Two Badger stabilizers are also part of the processing equipment. These are operated to remove butane from the light fraction and to secure the desired vapor pressure in the gasoline.

The refinery operates a sulfuric acid manufacturing plant with a capacity of 30 tons daily of 98 per cent acid. The plant incorporates the contact method using vanadium pentoxide catalyst. The acid is used in treating the heavy gasoline fraction in order to improve lead response. At the request of the controller of heavy industries and the director of war production, surplus acid in excess of refinery requirements is sold to certain local industries in Palestine, the sulfur equivalent to this surplus being provided by the government's appointed distributors.

For the chemical treatment of products the refinery has large facilities for acid, plumbite and caustic treating. These units are of standard design.

Cooling

An interesting feature of the refinery, which so far as the writer is informed, is not duplicated in any of the plants in the Western Hemisphere, is the water-cooling installation. It consists of two parabolic-type cooling towers. These are commonly used in power-plant installations and manufacturing operations in the United Kingdom and parts of Continental Europe. The towers, which are constructed of reinforced concrete, are 250 ft. high and are 200 ft. in diameter at the base. They are each designed to cool 2,000,000 gal. of water hourly from 117° to 90° F. at a wet-bulb temperature of 85° F. and a relative humidity of 75 per cent.

The towers were built by the company under the patent rights of Film Cooling Towers, Ltd. The cooling is entirely dependent on natural draft in the towers.

Warm water from refinery operations is collected in a common sump and is circulated over the cooling towers by turbine-driven 30,000-g.p.m. pumps. The cooled water collects in another common sump and is redistributed to the refinery by another set of turbine-driven 25,000-g.p.m. pumps. A connecting flume between the warm and cold-water sumps allows surplus tower circulation to flow back to the warm-water pump suction. Makeup water is fed into this flume at the rate of about 4 per cent of total tower circulation. The water is given a treatment of 5 p.p.m. of Calgon to inhibit scale deposition.

Steam Generation

The steam required by the refinery is supplied by four boilers of the Spearing bent-tube type with full water walls. They are fitted with oil and gas burners. Each boiler has a capacity of 150,000 lb. per hour of 500 lb. steam. All water is chemically treated before use.

This plant supplies the steam for three turbogenerators manufactured by English Electric Co., each having a capacity of 6,250 kw. These are operated with the 500-lb. steam. The turbines are of the drawoff type, each being designed to produce up to full load with a drawoff of 220,000 lb. per hour of process steam at 200 lb. pressure.

The office building of the company, located on the plant site, is modern in every respect. The refinery, being new, the modern features are also apparent in the plant hospital, restaurants for local and European staffs, store houses, and housing facilities for part of the staff.

Future Operation

With the war ended, changes in the method of operating the plant are probable. The present operation can be modified slightly, or the entire refinery can be reconverted to incorporate the original design of combination units and reforming. An accompanying diagram shows the main features of this combination-reforming operation.

Crude Units

Each of the three crude units processes up to 1,000,000 tons per year, or 28,000 bbl. daily (330 days per year) of normal stabilized Iraq crude oil. The products obtained are:

	Approx. vol. of cut
Gasoline (100° C. e.p.)	8%
Heavy benzine	10%
Naphtha	12%
Kerosene	13%
S.R. gas oil	17%
Reduction P.D. (200° C. e.p.)	5%
Cracked gas oil (flash point below 175° F.) (Pour point not above 15° F.)	7%
Residue	28%

Straight-run residue (40 per cent on crude) is also obtained when necessary. The gasoline is condensed under pressure to allow the retention of all the C_4, and its heavy end is well fractionated so as to obtain the highest octane rating.

A heavy gasoline fraction is required for the preparation of straight-run gasoline, though normally the greater part, if not all, of this cut is reformed together with the naphtha cut.

The maximum straight-run gas oil is required owing to the high demand for this product. The residue after removal of the gas oil being unsuitable for sale as a fuel oil, the reduction section of the plant is designed to convert this into low-cold-test components capable of blending into furnace oils. This operation involves a certain degree of cracking, but the pressure distillate obtained being of poor quality, the amount produced is as low as possible, consistent with the required quality of the fuel components. A cracked low-cold-test gas oil is considered of particular value. The residue is blended with other cracked products within the unit to give a furnace oil having a viscosity of 800 seconds Redwood 1 and an A.S.T.M. pour point of 35° F.

The two combined topping and reduction units are of Kellogg design. Each unit consists of a distillation section and a reducing section. The distillation side has a preflash tower system and an atmospheric distillation system. The reduction side consists of a reduction or residue cracking section, and a wax cracking section. Both operate with the same tower system.

There is also a depropanizer for the cracked pressure distillate, complete stabilization equipment being considered unnecessary as this cut has been reformed. Suitable blending arrangements are provided within the unit for providing the furnace oil to specification, a special feature being the use of a cracked light distillate for fluxing so as to release the maximum quantity of cracked gas oil. As shown in an accompanying flow chart, the crude is

first preheated by passing through a number of exchangers followed by a relatively small convection bank placed in the upper part of the crude furnace (B.1). The crude is then discharged into the primary preflash tower which operates at around 50 psi. and removes overhead roughly two-fifths of the gasoline fraction. The bottoms then flow into the secondary preflash tower which operates at substantially atmospheric pressure. The remainder of the gasoline passes overhead and to insure good fractionation a high reflux ratio is maintained; additional heat input is thereby required and is obtained by recycling some of the crude from the outlet of the crude furnace.

The overheads from both towers are mixed and leave the unit for subsequent stabilization. The reduced crude leaving the secondary preflash towers is pumped through a residue exchanger straight to the crude furnace (B.1) which is of the split-flow type. The heated crude is delivered into the atmospheric or crude flash tower which is of the conventional type with four side-stream drawoff connections. For the naphtha, kerosene, and upper gas-oil connections (this is used to give the S.R. gas oil) a three-section stripping column is used.

While soda injection is provided as an additional precaution against corrosion, no steam is injected into any of the fractionating towers mentioned above. The steam injected into the strippers and that coming from the soda flash drum are fed to a separate condenser followed by a water separator and any condensed oil led back into the atmospheric tower.

The heavy gas oil, drawn off from the lowest atmospheric-tower side-stream connection and the residue from this tower, are both fed across into the reduction section of the plant. The residue is charged direct into the reducing furnace (B.2) designed to give a partial cracking of the wax. From the outlet the oil flows to the base of an evaporator tower which is provided with a draw-off pan roughly halfway up. This pan collects a wax distillate cut plus the heavy gas oil from the atmospheric tower both of which are pumped through a wax cracking furnace (B.3) and thence back to the base of the same evaporator tower.

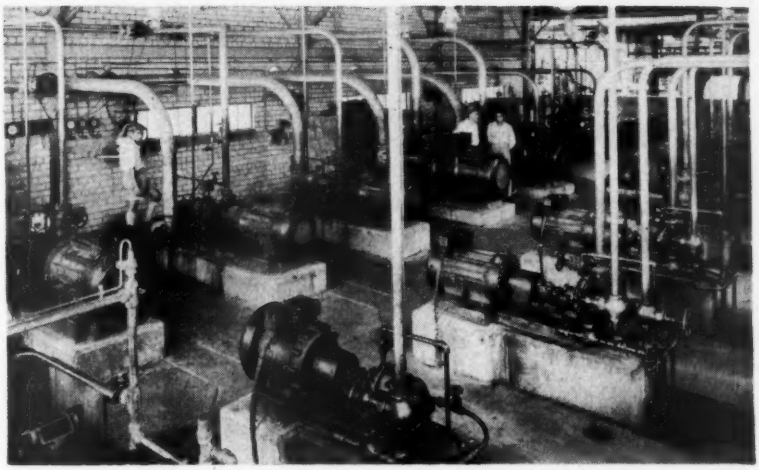
The pressure at the outlet of the reduction furnace is not higher than 150 psi. but the cracking furnace outlet is around 500 psi. The evaporator tower with the attached and subsequent equipment operates at 50 psi.

To complete the heavy-oil circuit, the residue from the evaporator tower drops into a vacuum flash tower, from which the pitch is withdrawn for fluxing and delivery as fuel oil and the distillate returned to the evaporator tower above the pan. The temperature conditions at the top of the evaporator are set so that all products heavier than gas oil are knocked back for passing through the cracking furnace and the gas oil and lighter ends pass on to a bubble tower (E.4) designed to separate out the pressure distillate overhead and a gas oil with some lighter ends as bottoms. The latter pass to a cracked gas oil stripper to give a specification product while any required proportion of the overhead is blended with the vacuum tower pitch and the remainder returned to the top of the evaporator.

The bubble tower overhead consists of unstabilized pressure distillate and this is depropanized in a small tower before release from the unit. To provide a correct charge for the cracking furnace the product falling into the evaporator tower pan needs some stripping. To do this with steam might introduce corrosion and other troubles so some unstabilized pressure distillate is used after evaporation in a special convection coil situated in the upper part of the cracking furnace.

Fluxing of both the reduction and cracking transfer lines is insured by a stream of cracked gas oil while pressure distillate is also used for fluxing the cracking transfer lines if necessary.

In mechanical design these units follow standard Kellogg practice, though additional cooling surfaces have been allowed, based on water at 85° F. All the pumps are motor-driven centrifugals except for a few small steam pumps for low-capacity duty and the motor-driven plunger-type soda-solution proportioning pumps. The furnaces are equipped with combination oil and gas burners.



Light-oil pump house

Reforming Units

The two reforming units are primarily designed for once-through reforming operation, but with a view to insuring full flexibility in the future, they are also capable of operating as clean gas-oil crackers, though at half throughput.

The designed throughput and production in barrels per day under these different conditions, are as follows for each unit:

Input—	Once through reforming	Gas oil cracking
Gas from reducing units	1,133	1,133
Naphtha or gas oil	10,000	5,000
Total charge	11,143	6,100
Output—		
Propane	1,257	674
Butane	1,328	571
Stabilized P.D.	6,428	3,114
Bottoms	585	1,400

Under both conditions the stabilized pressure distillate should have an octane rate of 71-72. Provision has been made to convert the plant for reversion by the addition of the necessary $C_3 + C_4$ charge pump. Such a charge would, however, reduce the input of the plant considerably while the output of pressure distillate would also be somewhat down.

Description

The naphtha charge is partially preheated and, passing through an accumulator, is pumped through the furnace to the evaporator. From this the residue falls to a fuel-oil flash tower, the corresponding distillate passing back to the bubble tower.

The overhead from the evaporator likewise goes into the bubble tower. The residue, or "cycle stock" is used for heating reboilers, is further cooled and used as reflux to the bubble and evaporator towers, and as flux to the transfer line.

XUM

The vapors from the bubble tower pass through a partial condenser into which may later be discharged the crude unit gases should the necessary 250-psi. compressors be installed in the future. The mixed vapors and liquid then pass to the absorber-stripper tower, the upper part of which acts as an absorber, using stabilized pressure distillate as absorbent while the tower stripping section is fitted with a reboiler to insure elimination of all the C_1 and C_2 from the liquid.

The liquid is charged to a debutanizing tower where the C_3 and any desired proportion of the C_4 are removed overhead to give a stabilized pressure distillate as a bottom product. The C_3 and C_4 vapors, after condensation, are passed through a depropanizing tower which gives specification butane as a residue and a propane cut as an overhead condensate.

From the top of the absorber-stripper tower the vapors contain all the C_3 and lighter cut, also some heavier components that were not absorbed. To obtain maximum recovery they are, therefore, fed to a secondary absorber through which circulates part of the cooled recycle stock which is then returned to the bubble tower.

In the design of these units provision has been made for the addition of the following: A high-pressure pump for C_3 and C_4 for reversion operation. H_2S removal equipment for the C_3 and C_4 charge to the depropanizing tower, likewise possibly needed for reversion. Also clay towers for the vapor phase treatment of the raw pressure distillate.

Pacific Section A.A.P.G., and Allied Groups Meet in Los Angeles

by L. P. Stockman

LOS ANGELES.—The Pacific Section of American Association of Petroleum Geologists held its twenty-second annual fall meeting here November 8 and 9 at the Ambassador Hotel and the Society of Economic Paleontologists and Mineralogists held its annual meeting at the Clark Hotel, Thursday evening, November 8. For the first time, these annual meetings were preceded by a meeting of the Pacific Coast District Society of Exploration Geophysicists, at the Ambassador Hotel, November 7. The A.A.P.G. program listed 14 papers and discussions and included Dr. Chester R. Longwell, professor of geology at Yale University, and Dr. Bailey Willis, professor emeritus of geology, Stanford University. Both are distinguished lecturers of the A.A.P.G.

The meeting of the Pacific Section of the Society of Economic Paleontologists consisted of a business session and one technical paper by Glenn C. Ferguson of Bakersfield. The S.E.P. had eight technical papers, and talks by A. C. Rubel, vice president of Union Oil Co., Henry R. Cortes of Magnolia Petroleum Co., Dallas, and president of the society, and another by Howard C. Pyle, vice president of Bank of America. The attendance at all meetings was excellent, it being noted especially that many of those in military service have returned to civilian life and a number of others are on terminal leave.

R. E. Atwill, a member of Union Oil Co.'s geological staff, operating as research geologist, exploration department, was elected president of the Pacific Section of A.A.P.G. succeeding Glenn H. Bowes of Continental Oil Co. who becomes ex officio member of the executive committee. Vincent W. Vandiver, who was secretary-treasurer last year, was elected vice president succeeding Robert T. White. A. F. Holston, Tide Water Associated Oil Co., was elected secretary-treasurer.

The Pacific Coast district of S.E.P.M. elected Frank Dreyer, Union Oil Co. as president succeeding Stanley S. Siegfuss, Pacific Western Oil Co. Howard Anderson of Standard Oil Co. was elected secretary succeeding Jack Ruth of the same company.

The Society of Exploration Geophysicists elected P. P. Gaby, Geophysical Service, Inc., and Charles H. Dresbach, Western Gulf Oil Co., to a committee charged with the responsibility of preparing for the next annual meeting. Attendance at the 3-day meeting was 510, many members attending all 3 days, others confining their attention to certain technical sessions.

GLENN H. BOWES *STANLEY SIEGFUSS* *O. C. LESTER*

FPC Sets New Place and Date for Texas Hearing

WASHINGTON.—Federal Power Commission has postponed to January 28, 1946, in Houston, the hearing previously set for December 10 in Dallas in the commission's natural-gas investigation. The specific meeting place in Houston will be announced later. The change was made in response to a request of the Railroad Commission of Texas and the steering committee of Gov. Coke Stevenson.

I.N.G.A.A. Postpones Its Membership Meeting

WASHINGTON.—Because of the action of Federal Power Commission in changing the time and place for its Texas hearing in the natural-gas investigation, Independent Natural Gas Association of America has decided to hold its annual membership meeting at the Texas State Hotel, Houston, on January 28, on which day the FPC hearing will begin. Meeting was scheduled previously to be held in Dallas December 10.

PEPA Elects Officers

DALLAS.—Petroleum Electric Power Association of America elected officers as follows at its annual meeting here: President, H. C. Levois, Port Arthur, Tex.; vice president, Duane Landon, St. Joseph, Mo.; secretary-treasurer, Paul Griffith, Pine Bluff, Ark. Added to the board of directors were B. F. Thompson, Tulsa; W. B. Woodward, Hammond, Ind., and Lee Riley, Kansas City, Mo.

Secondary-Recovery Research Progress Is Chronicled

STATE COLLEGE, Pa.—Progress in research on secondary recovery of petroleum was reported in a number of papers presented here recently at the ninth annual technical meeting of the School of Mineral Industries, Pennsylvania State College, in cooperation with the Pennsylvania Grade Crude Oil Association. Research laboratories of the school were open for inspection. An open forum on oil-production problems was held the second day of the meeting in which oil producers and members of the research staff participated.

Abstracts of papers follow:

Selective Plugging by Smokes In Air-Gas Drive

R. F. NIELSEN and S. T. YUSTER.

THE use of aerosols such as dusts or smokes for selective plugging in air or gas-drive operations seems a likely possibility, just as aquasols, such as wax dispersions, have served as selective plugging agents in water drive. A number of fine powders having ultimate particle sizes down to a fraction of a micron were tried, but sufficient dispersion could not be obtained by simple means to give selective plugging in the desired permeability range.

Smokes of parrafin, stearic acid, rosin, and ammonium chloride prepared by a condensation method showed selectivity in the range from 90 to 700 md. Observations were made on the tendency of the smokes to stick to pipes and connections. It was found that the greater the capacity of the air or gas stream to cool the vapor of the smoke material, the less the tendency of the smoke to stick to connections. Factors involved in the generation of smokes, such as thermal balance and design of apparatus for field use, are discussed.

Wax Saturations in Oil Sands

J. C. CALHOUN and S. T. YUSTER

DURING the routine determinations of oil saturation on cores from a Pennsylvania pool, the extractable material behaved abnormally. Upon examination it was found to be extremely high in wax content. The conclusion was reached that free wax existed in the sand, which was substantiated by tests upon the crude oil. Because of the presence of this wax the oil saturation as calculated by ordinary methods was in error. A method was developed for calculating the true oil and wax saturations of the cores. Wax contents up to 6 per cent were found.

Measurements were made upon this crude oil to determine its paraffin point. This temperature was in close agreement with the formation temperature which indicated that the oil was saturated with wax in the formation. This criterion was used as a test on oils from other areas to determine if the condition existed elsewhere. On two other Pennsylvania-crude samples the paraffin points and formation temperatures agreed closely. This points to a possibility of appreciable wax saturations and warrants further study.

Field Effective Permeabilities And Shot-Well Radii

S. T. YUSTER.

A METHOD has been developed based upon certain theoretical deductions which makes it possible under certain conditions to calculate the effective permeability of a formation to flood waters and the effective shot radius. The method depends upon the linear relationships between the logarithm of the cumulative volume of water injected and the reciprocal of the injection rate. The slope of such a line is a function of the effective permeability and the theoretical Y intercept is some function of shot-well radius. Studies of field data indicate a wide variation in relative water permeabilities with a possibility existing of a reaction between the waters and the formation. A variation in shot responsiveness of different formations was also deduced from this study.

Predictions of Behavior In Air-Gas Drive

R. J. DAY and S. T. YUSTER

AN equation has been derived for the behavior of an air-gas drive operation based upon an empirical relationship found to hold for laboratory experiments on long cores. This equation predicts that the reciprocal of the oil-production rate should be a linear function of the time. This relationship was tested on the production of several leases and found to hold remarkably well. A second equation was derived for predicting the cumulative oil production on a property. The theoretical predictions agreed very closely with the actual production.

Graphical Prediction of Water Flooding Intakes

S. T. YUSTER

THE prediction of water inputs in a water-flooding operation is necessary for determining water requirements and oil production. A simple and rapid graphical method has been developed for obtaining such data. The method is very flexible and of the four variables effective permeability, time, cumulative volume, and injection rate, any two can be fixed and the other two can be computed graphically. Certain type problems are considered illustrating the application of the graphs.

Shield Heads Texas Unit Of Oil and Gas Association

FORT WORTH.—Fred W. Shield, San Antonio, was chosen president of the Texas Mid-Continent Oil and Gas Association at its meeting here November 9. George C. Gibbons and Eugene McElvaney, both of Dallas, were reelected executive vice president and treasurer respectively.

Joe H. Russell, vice president of Gulf Oil Corp., Houston, was chosen from among major company executives to receive the association's annual award for outstanding service to the industry.

J. C. Hunter, of Abilene, was the independent member chosen for a like award. Charles F. Roeser received the award for Hunter, who was in a hospital at Altoona, Pa., and died there Sunday.

John R. Suman, vice president and director of Standard Oil Co. of New Jersey, spoke at a dinner meeting of the association's directors. He predicted that postwar gasoline consumption might rise to such a high level that it would be necessary to save the nation's resources of light crudes for the sole processing of motor and aviation fuels.

Suman quoted demand forecasts made before the O'Mahoney committee in the Senate that domestic needs for all petroleum oils, including exports, would be 5,100,000 bbl. daily by 1950 and 5,800,000 by 1965. This compares with total demand of 3,900,000 bbl. daily in 1939 and 5,600,000 just before V-J Day.

This demand, Suman said, will bring a gradual increase in the gasoline cut from crude oil and a corresponding reduction in the amount of fuel oils to be processed. A deficit in fuel oil, Suman said, would have to be met by imports of foreign crude.

Pennsylvania Grade Group Elects Clinger President

OIL CITY, Pa.—W. F. Clinger, head of Clinger Oil & Gas Co., and vice president and treasurer of Superior Oil Works, Warren, Pa., was elected president of Pennsylvania Grade Crude Oil Association to succeed D. T. Andrus, who had been president since June 1943.

W. F. CLINGER

B. T. Haskins, Wellsville, N. Y., was chosen first vice president to succeed A. C. Simmons, of Bradford. D. T. Ring, Columbus, Ohio, was reelected second vice president. The revised Anglo-American oil treaty was approved and the Senate was urged to ratify it.

Clinger headed the association as president from 1937 to 1940. He has been a director since 1934. Andrus said he resigned to devote more attention to his oil-producing activities.

XUM

Shell's Colombian Wildcat Reports Show

Several stands of low-gravity oil were reported obtained last week in a drill-stem test of Cia. de Petroleo de Colombia 2 San Martin, in the Llanos region of Colombia, according to a recently published issue of Colombian Oil-News Digest. The oil came from the Tertiary level around 6,560 ft. A more widespread and intensified exploratory program will probably be brought about by this success.

The Llanos region covers about half of Colombia's prospective oil lands and the immediate goal is to find good-quality oil to be exploited at the rate of about 100,000 bbl. per day, to justify a 700-mile pipe line to Caribbean tidewater. Llanos oil must compete with Near East oil, but when and if found, would have the advantage of shorter pipe-line distances to offset Near East's low cost advantage.

Four Named to New Posts By International Petroleum

TORONTO, Ont. — Directors of The International Petroleum Co., Ltd., last week elected F. B. Bimel chairman of the board and Philo Maier president. Both offices formerly were held by the late R. V. LeSeuer. Paul Lambright and B. A. Myers were elected vice presidents.

Bimel has been a director of International Petroleum since 1923 and was made a vice president in 1944. Maier formerly was chief engineer and later president of Andian National Co., which operates a pipe line in Colombia. He has been a resident of Toronto for many years, but has spent part of his time in South America.

F. B. BIMEL

PHILO MAIER

PAUL LAMBRIGHT

B. A. MYERS

Lambright began his career in the United States with The Carter Oil Co., and served subsequently in Argentina, Sumatra, Romania, and the Northwest Territories. At the time of the Nazi invasion of Romania, he was manager of the Romano Americano Oil Co. at Bucharest. He has recently been in South America for International Petroleum.

Myers became associated with International Petroleum through Tropical Oil Co., a subsidiary, and became a director in 1936. He has had wide experience in producing and drilling and has lived in Venezuela, Colombia, and Peru. International Petroleum is a subsidiary of Imperial Oil, Ltd., of Toronto.

DEATHS

J. C. Hunter, 55, of Abilene, Tex., president of Mid-Continent Oil and Gas Association since 1938, died November 11 in an Altoona, Pa., hospital, where he had been taken November 1 after being stricken on a train. He was an active figure in the oil and gas industry of the Southwest from 1924, when, with the Grisham brothers, West Texas ranchers, he formed a partnership which 2 years later became Grisham-Hunter Corp., of which he was made vice president. Gregg Oil Co. and Brown Eagle Oil Co. were organized later, and he was chosen president of each. Hunter represented Texas on Interstate Oil Compact Commission. He had served as a member of the Petroleum Industry War Council, president of West Central Texas Oil and Gas Association, director of Independent Petroleum Association of America, and had important banking interests.

Don Sprague Bowers, 58, president of W. C. Norris Manufacturer, Inc., Tulsa, died of a heart attack November 11. He joined Norris in 1915, became manager 20 years ago, and when the company was incorporated in 1935 was made executive vice president, a post he held till last June, when he was named president upon the death of W. C. Norris. Educated at Hanover College, Bowers went to Tulsa in 1909 and worked for Gulf Pipe Line Co. several years before beginning his service with Norris.

William J. Sloan, 64, widely known oil operator and a director of Independent Oil Producers Association of America, died of a herat attack November 9 at Bradford, Pa., in the office of Sloan & Zook Co., of which he was vice president. In partnership with Ralph T. Zook, he had drilled wells and operated refineries in western Pennsylvania since 1917.

J. Leroy Green, 59, division manager for Magnolia Petroleum Co. in Oklahoma City 24 years, died November 11.

Hugh G. Curran, 79, retired developer of oil properties in Oklahoma, Texas, and Mexico, died November 4 in Pelham Manor, N. Y.

Frederick L. McCoy, 54, former oil operator in West Texas, died of a heart attack November 7 in Los Angeles.

George W. Whitman, 93, a pioneer in oil fields of Pennsylvania, Ohio, West Virginia, New York, and Indiana, died November 5 in Tulsa. Whitman at one time was one of the most important operators in the Ohio fields. Until 10 years ago, when he retired, he was active in the Burkburnett field, Texas. He was born near the site of the Drake well.

Elmer W. Mong, 72, who spent most of his life in the oil business, died October 31 in Shippenville, Pa. His interests had taken him to Peru, Ecuador, and Burma, besides oil areas of several states in this country.

William B. Milton, Jr., 40, district geologist for Houston Oil Co. of Texas, met death by drowning in Brays Bayou, where the body was found after Milton had been missing 5 days.

John B. Schuyler, for many years identified with the oil-equipment industry on the West Coast, died unexpectedly in Los Angeles October 29. He joined the materials division, Petroleum Administration for War, in 1941, later worked in its Los Angeles office, and then was transferred to Denver as director of materials in District 4. His home was in Beverly Hills, Calif.

W. H. Reardon, 41, production superintendent for Shell Oil Co., Inc., in the Centralia, Ill., area, died of a heart attack November 7.

Dr. E. H. Boomer, 45, chairman of the Petroleum and Natural Gas Conservation Board of Canada since 1943 and commissioner on the Natural Gas Utilities Board of Alberta, died in Edmonton of a heart attack. Dr. Boomer graduated with a B.S. degree from University of British Columbia in 1920 and since 1925 had been connected with the University of Alberta. He did preliminary work on the atomic bomb.

XUM

OK

is unanimous verdict of men who directed war in commenting on distinguished service oil industry rendered during national emergency.

Gen. George C. Marshall

Gen. Henry H. Arnold

Adm. Ernest J. King

Generals Marshall and Arnold and Admiral King, commanders of the Army, the Air Forces and the Navy, have been unstinting in their praise for the miracles performed by the oil industry and the Petroleum Administration for War in meeting all wartime requirements for petroleum.

A SPECIAL SECTION — This Special Section tells the story of how the industry-government petroleum team drove through a tremendous supply job on a global basis in order that no military operation should fail. Key oil men serving both on industry committees and with PAW are listed to pay the credit due these individuals.

PETROLEUM WAR TEAM

GOVERNMENT

INDUSTRY

PETROLEUM ADMINISTRATOR for WAR
Harold L. Ickes

DEPUTY PETROLEUM ADMINISTRATOR
Ralph K. Davies

PETROLEUM ADMINISTRATION for WAR
NATIONAL OFFICE

Determine Overall Objectives, Policies and Programs
Exercise general direction, coordination and
control over their accomplishment.

PROGRAM | RESEARCH | FACILITY SECURITY | MATERIALS | CONSTRUCTION

DOMESTIC OPERATIONS: PRODUCTION | NATURAL GAS & GASOLINE | REFINING | SUPPLY & TRANSPORTATION | DISTRIBUTION & MARKETING

FOREIGN OPERATIONS: FOREIGN PRODUCTION | FOREIGN REFINING | FOREIGN SUPPLY & DISTRIBUTION

ADMINISTRATIVE | ORGANIZATION PLANNING | MANPOWER COUNSELOR | EXECUTIVE SECRETARY | SPECIAL ASSISTANTS | PUBLIC RELATIONS | LEGAL

P. A. W. DISTRICT OFFICE
DIRECTOR - IN - CHARGE

Administer National Policies and Programs within District,
Functioning as Primary Point of Contact with the Industry.

FACILITY SECURITY | MATERIALS | CONSTRUCTION | PRODUCTION | NATURAL GAS & GASOLINE | REFINING | SUPPLY & TRANSPORTATION | DISTRIBUTION & MARKETING | ADMINISTRATION | LEGAL

XUM

5 DISTRICT TEAMS

NEW YORK
CHICAGO
HOUSTON
DENVER
LOS ANGELES

DISTRICT GENERAL COMMITTEE

(created by the Petroleum Administration for War)

GENERAL CHAIRMAN

Chairmen of Functional Committees ⊛

Assist PAW in Mobilizing the Resources of the Industry to carry out PAW Policies and Programs in the District

DISTRICT COMMITTEES

FACILITY SECURITY | MATERIALS | CONSTRUCTION | PRODUCTION ⊛ | NATURAL GAS & GASOLINE ⊛ | REFINING ⊛ | SUPPLY & TRANSPORTATION ⊛ | DISTRIBUTION & MARKETING ⊛ | MANPOWER | STATISTICAL

PETROLEUM BOARD

Composed of

Chief Executives of Government Agencies concerned with Petroleum Affairs (PAW, State, War, Navy, RFC, WPB, OPA, WSA, ODT, FEA, CIAA, OBPR)

Coordinate the Policies and Programs of the Government Agencies which directly or indirectly affect the production, distribution, and use of petroleum products.

FOREIGN PETROLEUM COMMITTEE

Composed of

Key executives of Government Agencies concerned with Foreign Petroleum Affairs (PAW, State, War, Navy, WPB, WSA, FEA, CIAA, OBPR)

Coordinate the Policies and Programs of the Government Agencies which directly or indirectly affect the production, distribution, and use of petroleum products abroad

PETROLEUM SUPPLY & DISTRIBUTION BOARD

Composed of

Representatives of Government Agencies concerned with Supplying Petroleum abroad (PAW, War, Navy, WSA, OBPR)

Deal with Problems of World wide Transportation of Petroleum Supplies needed for military and essential civilian uses.

PETROLEUM REQUIREMENTS COMMITTEE

Composed of

Representatives from Government Agencies which are Claimants for Petroleum Products (PAW, War, Navy, WPB, WSA, ODT, FEA, WFA, NHA, OPA)

Determine Requirements for Petroleum Products for military and civilian uses, and recommend Allocation of available Supplies

PETROLEUM INDUSTRY WAR COUNCIL

(created by the Petroleum Administration for War)

William R. Boyd, Jr. - Chairman

78 Representative Leaders of all branches of the American Petroleum Industry

Advise Petroleum Administrator and Deputy Administrator in the formulation of National Policies and Programs.

NATIONAL COMMITTEES

NATIONAL OIL POLICY | PETROLEUM ECONOMICS | TECHNICAL | PROTECTION of PETROLEUM FACILITIES | PRODUCTION | NATURAL GAS & GASOLINE | REFINING | SUPPLY & TRANSPORTATION | DISTRIBUTION & MARKETING | PRODUCT CONSERVATION | MANPOWER | REQUISITIONS | DISPOSITION OF GOVT. OWNED FACILITIES

FOREIGN OPERATIONS COMMITTEE of the INDUSTRY

(created by the Petroleum Administration for War)

Orville Harden - Chairman

Membership of Representatives of American Oil Companies operating abroad

Advise Petroleum Administrator and Deputy Administrator in the formation of foreign Oil Policies and Programs.

FOREIGN COMMITTEES

MATERIALS | PRODUCING | REFINING | CARIBBEAN AREA | NEAR EAST & FAR EAST | WEST AFRICA | EUROPE | LATIN AMERICA | LUBRICATING OILS | PACKAGE GOODS | SPECIAL COMMITTEES — American Bankers Economic Survey

W. R. Boyd, Jr., chairman, Petroleum Industry War Council, and president, American Petroleum Institute

Harold L. Ickes, administrator, Petroleum Administration for War (right), and Ralph K. Davies, deputy administrator, PAW

OIL'S WAR STORY: PLENTY,

In modern war, victory goes to the side with sufficient supplies of oil to move the most machines to points where they can hurl steel, explosives, and flame at the enemy until he surrenders. Armor and oil are substituted for flesh and blood. Victory was ours largely because the American petroleum industry supplied ample power to move our machines. These pages contain a brief highlight of the oil war and a partial list of the oil men who contributed to victory.

by Henry D. Ralph and Charles J. Deegan

The decisive factor in the war was petroleum. The side that supplied the kind and quantity of petroleum products where and when they were needed, while denying the enemy his available supply, won the war. Allied military forces, backed primarily by the American petroleum industry, succeeded; the Axis forces, backed by their petroleum industries, failed.

Lack of petroleum products was the primary cause of the military downfall of the Axis powers. This is the sum and substance of the story told by both the Germans and Japanese, and confirmed by American observers who have been examining the records and personnel of the German and Japanese military high commands.

When their aviation-gasoline supplies became insufficient, the Axis countries had to curtail the training time of their pilots. This led to inferior pilots who gradually lost control of the air over their home countries, which led to still further shortages of fuel through Allied bombing. Finally, they did not have enough aviation gasoline to put even a fraction of their available planes into the air. Then came destruction of their transportation systems by bombing, and the Axis military machines ground to a stop, completely out of fuel.

In sharp contrast to the story of the Axis powers, no Allied military operation was ever held up for lack of petroleum supplies. This situation was not due to lack of efforts by the enemy to cut off the petroleum supplies of the Allies. In the dark days of 1942 they tried and came perilously close to succeeding. A total of 600,000 bbl. daily of crude-oil production was lost to the Allied cause through enemy action. Over a million barrels daily of crude and products needed on the eastern seaboard of the United States was almost cut off. Only the ingenuity and herculean labor of the men of the petroleum industry checked this attempt to paralyze the industrial economies of both the United States and the British Isles.

All major wars must be depicted by over-simplifying them into a series of major battles, ignoring the thousands of details that were essential to these battles. The oil war is no exception. The broad picture can only be described in a series of major battles that necessarily fail to give credit to the scores of minor engagements that made victory possible.

The Battle for 100-Octane Production

THE battle for 100-octane production was the decisive battle of the oil war, just as the battle for oil was the decisive factor in the whole war. The 100-octane battle was a grueling grind from start to finish. The reason is simple. This was the factor that gave our pilots, first an advantage, then a superiority, and finally command of the air. At each gain, our air forces stepped up the tempo of their attack in order to give the enemy no chance to recover. Therefore each advantage

Chairmen of the five regional industry committees with Ickes and Davies, on the occasion of the first PIWC meeting: W. H. Ferguson, Frank Phillips, R. K. Davies, H. L. Ickes, A. L. Weil, Charles F. Roeser, and John A. Brown

WHEN AND WHERE NEEDED

gained resulted in another upward revision of the quantities of 100-octane required. Consequently the maximum effort in this battle was reached only on the very last day of the war.

Fortunately the industry's foresight was greater than that of the early military procurement groups, and long before Pearl Harbor, a vast amount of preparatory work had been done. From Pearl Harbor to the day the war ended, the volume requirements and the time goals set by the military forces were constantly being revised. These revisions were always upward for volume and always shortening the time limit. In addition a very substantial burden was added by the constant revisions in specifications. These revisions always resulted in quality improvement, but invariably reduced the volume of finished product that could be made from a given quantity of crude oil by any given process.

In effect, two tasks were undertaken simultaneously. In one, by the bits-and-pieces method, taking small quantities of various components from many plants and bringing them together, relatively substantial increases in volume were obtained quickly. But this was only a "quickie program," a makeshift to meet the emergencies that would not wait on construction of new mass production plants. In the second, the bulk of a billion dollars was spent, in building new plants. Due to the rapid changes in specifications resulting from intensive research on fuel quality, this meant taking new processes from laboratory to mass production facility construction, without a pilot plant intermediate stage.

In accomplishing these tasks, the entire refining industry of this country was literally taken apart and fitted together on a new pattern. Moreover, this had to be done without interrupting the vital flow of normal petroleum products that were essential to uninterrupted operation of a civilian economy.

From the very beginning no steps were taken without advance notice to the industry. The refining division of PAW became one of its largest divisions, but the key men on its payroll, practically all contributed by the industry, did not begin to measure the amount of executive and technical brains at its command. District refining committees and their subcommittees, PIWC committees and their subcommittees, technical subcommittees, working in liaison and with excellent coordination under trying circumstances, mobilized the cream of American refining knowledge. Working with their fellow refining men in the industry, the whole team won the battle, and attempts to single out individuals or groups for special mention would be unrealistic. It was teamwork that won the battle.

The Battle of Supply and Transportation

THE battle of supply and transportation was the first major battle of the oil war. Had the Nazis won that battle, the whole war would have been lost quickly in 1942, before the power of the United States could be mobilized and sent into action. As in the case of 100 octane, the industry's foresight exceeded that of the military, and its transportation planning and organization work prior to Pearl Harbor proved to be the thin margin that staved off threatened disaster several times, before the tide of battle finally shifted and victory was assured.

Apparently only the petroleum industry and the German high command realized that the industry is one of the world's greatest users of transportation, requiring a daily movement totaling millions of ton miles. It is practically the only industry with a privately owned transportation system for the mass movement of its raw materials and products over long distances. This system has a dual backbone of tankers and pipe lines.

In accordance with peacetime economics, only the great interior of the country was served by pipe-line networks. In other areas the pipe lines were feeders to the coast, where the cheaper tankers picked

XUM

Deputy Coordinator Davies and his chief assistants in staff meeting: R. E. Allen, G. M. Sessions, E. B. Swanson, J. A. Fanelli, S. W. Crosthwait, J. T. Duce, D. R. Knowlton, E. DeGolyer, R. E. Davies, B. K. Brown, W. R. Lange, R. T. Collier, W. F. Huff, W. D. Mason, E. H. Poe, W. B. Heroy, G. W. Orton

up the burden. Or the lines were feeders inland from the coastal areas receiving supplies by tanker.

The northeast part of the United States, with its concentration of industry and population had little or no oil, relying upon tanker receipts from the southwestern United States and the Caribbean area countries. The thin line of tankers moving up the east coast constituted a jugular vein. This the submarines almost severed, and in doing so came perilously close to paralyzing the industrial economy of both the northeast and the British Isles, which were also dependent on tanker supplies.

The strategic situation when the battle opened was this. The petroleum industry had its privately owned transportation system, consisting of tankers, pipe lines, lake tankers, river and intracoastal barges, tank cars, and trucks. All were interwoven into a pattern dictated by peacetime economic competitive considerations, and were often geared to the integrated operations of a single company. The only surplus that existed was tank cars, which were becoming obsolete. The average age of the 112,000 tank cars on hand was 18 years.

When the battle ended, the entire transportation and supply system of the United States had been torn apart, rearranged in an entirely different pattern, and many new links built, including the famous big-inch and little big-inch pipe lines. Not only had the transportation system been rearranged, but the sources of supply had been subjected to many shifts. A crude-oil and refined-product distribution system built up gradually over a 30-year period was also arranged along with the transportation, with the bulk of the task performed in 2 years, in the face of shortages of material and manpower.

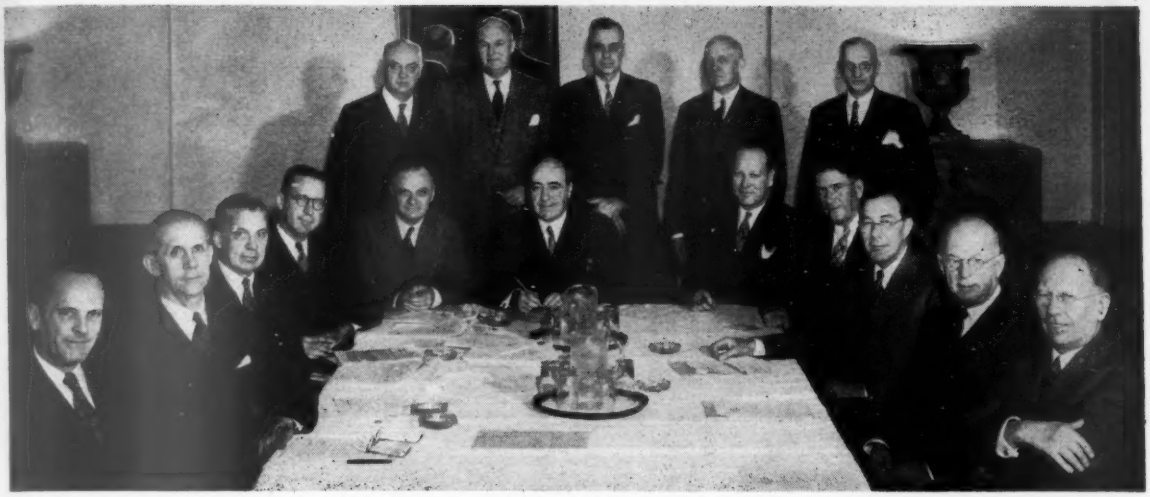
In rearranging the transportation, refiners had to be allocated new sources of crude supply, and distributors had to be allocated to new refinery sources. Transportation of all kinds, regardless of ownership, was integrated into a national unit, with efficiency measured only by ton miles of product handled per ton of steel.

Obviously, such a gigantic problem, made up of thousands of smaller problems, each complex in itself, was solved only by the combined efforts of thousands of oil men. Sailors, river men, railroad men, pipe liners, truck drivers, oil producers, oil refiners, and marketing men, all pulling together, won the battle.

Battle for Crude Oil

THE battle for crude oil was slow in developing and like the 100-octane battle, reached its peak practically on the day of final victory. In most sectors of the war, the story was, from the beginning—"too little, too late," to a happy ending of "too much, too soon". The battle for

PIWC Synthetic Rubber Committee: Jacob France, W. F. Humphrey, J. E. Pogue, Dr. R. E. Wils... J. H. Pip... R. van der Woude, Dr. Alexan... Sachs.



PIWC Economics Committee: Seated—Howard Page, A. Jacobsen, R. S. Merriam, S. P. Coleman, Fred Van Covern, Dr. R. E. Wilson, Allan H. Hand, Eugene Holman, A. C. Mattei, and O. D. Donnell. Standing—C. F. Roeser, W. A. Jones, B. B. Jennings, J. F. Drake, and W. H. Ferguson

crude oil was almost the reverse; in the beginning there was an ample supply, at the end, the industry was striving grimly for—"enough, in time."

After Pearl Harbor, every pound of steel was precious and the time element of its usefulness had to be weighed. An entire new navy had to be built, tanks and guns by the thousands, ships by the hundreds, ammunition by the thousands of tons. These had to come first. For the moment there was enough crude oil; the future had to be a gamble. Steel for drilling wells was cut to the bone.

The problem was to get the maximum amount of oil per ton of steel used. Complicating this major problem were the minor factors, often contradictory, of availability of oil to the transportation system when found, and the long run necessity for greatly increased wildcatting to find new reserves.

The only workable solution to these problems was wider spacing. This was put into effect, at first drastically to meet the emergency, then gradually modified to fit the peculiar regional conditions in each area. Wildcatting was stepped up rapidly and while the results will not be clear for another 2 years, the answer will probably be satisfactory.

Battle for Materials

THE battle for materials was strange. It was fought not with an enemy, but with friends and allies. Nevertheless to the petroleum industry it was a crucial struggle. In the beginning, neither the military nor the civilian authorities in charge of doling out materials had any conception of the important part that oil was to play. There was an end, in which oil men received every consideration from the joint chiefs of staff. In between there was a long internal struggle.

Gradually these men hammered home the necessity of materials for the industry. Little by little they won respect for the way in which they accomplished much with little. Firmly and insistently they battled for autonomy in handling materials within the industry. They fought constantly against making it subject to regulations well designed for general manufacturing, but totally unsuited to petroleum.

There were always conflicts between urgent programs for critical items. The 100-octane-plant requirements conflicted with Navy requirements for destroyers, and with those of new power plants for such war industries as airplane and tank manufacturers. Steel for the big-inch and little big-inch pipe lines was the subject of several major battles that went to the joint chiefs of staff for final approval. The materials men of the industry had to be diplomats, fighters, misers, and marvels of ingenuity, all combined.

J. H. Pipkin, W. W. Gary, W. S. S. Rodgers, A. H. Hand, Frank Phillips, C. F. Roeser, J. A. Brown, Sachs, and E. W. Isom

PIWC Production Division: Seated—D. H. Hogan, B. A. Hardey, R. T. Zook, C. P. Watson, D. T. Andrus, Ferd Spang, P. H. Bohart O. D. Donnell, W. S. Hallanan, J. B. Brown, G. A. Hill, Jr., R. S. Shannon, E. E. Pyles, W. T. Payne, J. S. Bridwell, J. C. Hunter, and H. B. Fell. Standing—E. B. Reeser, W. T. Heroy, M. Hoffman, G. W. Noble, N. G. Dumbros, Maj. L. W. Storms, E. E. Robbins, C. P. Parsons, J. R. Donnell, R. B. Brown, J. M. Lovejoy, and J. E. Heston

Petroleum Industry War Council

(Created by Petroleum Administration for War)

William R. Boyd, Jr., chairman

Allan H. Hand, executive secretary-treasurer

Robert E. Allen, Russell B. Brown, Francis J. Connor, Fayette B. Dow, Joseph L. Dwyer, and Joseph E. Pogue

K. S. Adams, Phillips Petroleum Co., Bartlesville, Okla.

Don T. Andrus, Pennsylvania Grade Crude Oil Association, Oil City, Pa.

T. H. Barton, Lion Oil & Refining Co., El Dorado, Ark.

Burt R. Bay, Northern Natural Gas Co., Omaha.

C. S. Bessemyer, Gilmore Oil Co., Los Angeles.

Sidney Belither, Shell Oil Co., Inc., San Francisco.

M. L. Benedum, Benedum Trees Oil Co., Pittsburgh.

Paul G. Blazer, Ashland Oil & Refining Co., Ashland, Ky.

J. S. Bridwell, Bridwell Oil & Gas Co., Wichita Falls.

**John A. Brown*, Socony-Vacuum Oil Co., Inc., New York.

Frank Buttram, Independent Petroleum Association of America, Okhoma City.

**J. W. Carnes*, Consolidated Oil Corp., New York.

H. Earl Clack, Clack Oil Co., Havre, Mont.

Robert H. Colley, Atlantic Refining Co., Philadelphia.

H. D. Collier, Standard Oil Co. of California, San Francisco.

Howard A. Cowden, Consumers Cooperative Association, No. Kansas City.

Henry M. Dawes, Pure Oil Co., Chicago.

Sylvester Dayson, Premier Oil & Refining Co., Longview, Tex.

R. E. Decker, Plymouth Oil Co., Detroit.

B. E. Devere, Independent Refiners Association of California., Los Angeles.

H. W. Dodge, formerly with The Texas Co., New York.

O. D. Donnell, Ohio Oil Co., Findlay, Ohio.

J. Frank Drake, Gulf Oil Corp., Pittsburgh.

J. H. Dunn, Natural Gasoline Association of America, Tulsa.

S. B. Eckert, Sun Oil Co., Philadelphia.

**W. S. Farish*, Standard Oil Co., (New Jersey), New York.

H. B. Fell, Simpson-Fell Oil Co., Ardmore, Okla.

W. H. Ferguson, Continental Oil Co., Denver.

Jacob France, Mid-Continent Petroleum Corp., Baltimore.

R. W. Gallagher, Standard Oil Co., (New Jersey), New York.

B. I. Graves, Tide Water Associated Oil Co., New York.

Walter S. Hallanan, Plymouth Oil Co., Pittsburgh.

D. P. Hamilton, Root Petroleum Co., Shreveport.

Jake L. Hamon, Cox & Hamon, Inc., Dallas.

Orville Harden, Standard Oil Co. (New Jersey), New York.

B. A. Hardey, Independent Petroleum Association of America, Tulsa.

Robert W. Hendee, Colorado-Interstate Gas Co., Colorado Springs.

C. L. Henderson, Western Petroleum Refiners Association, Wichita.

Fred W. Herlihy, National Oil Marketers Association, Orangeburg, S. C.

Geo. A. Hill, Jr., Houston Oil Co. of Texas, Houston.

Dana Hogan, Hogan Petroleum Co., Los Angeles.

W. T. Holliday, Standard Oil Co. (Ohio), New York.

Eugene Holman, Standard Oil Co. (New Jersey), New York.

Howard P. Holmes, American Association Oilwell Drilling Contractors, Dallas.

Frank E. Holsten, Gulf Coast Refiners Association, New Orleans.

D. W. Hovey, Gulf Coast Refiners Association, Houston.

William F. Humphrey, Tide Water Associated Oil Co., San Francisco.

J. C. Hunter, Mid-Continent Oil & Gas Association, Abilene, Tex.

A. Jacobsen, Amerada Petroleum Corp., New York.

B. Brewster Jennings, Socony-

PIWC Distribution and Marketing Committee: Seated—C. B. Watson, H. E. Clack, J. A. Lentz, Mrs. Frances O'Keefe, B. L. Majewski, Walter Hochuli, C. S. Beesemyer, and S. B. Eckert. Standing—R. E. Decker, E. V. Weber, Fred Herlihy, P. L. Howard, Walter DuMont, H. L. Thatcher, R. W. McMillan, and Roger Wilkinson

Vacuum Oil Co., Inc., New York.

C. A. Johnson, Independent Refiners Association of California, Inc., Los Angeles.

Charles S. Jones, Richfield Oil Corp., Los Angeles.

Roy B. Jones, Panhandle Producing & Refining Co., Wichita, Falls.

W. Alton Jones, Cities Service Co., New York.

J. Sayles Leach, The Texas Co., Houston.

J. A. Lentz, Continental Oil Co., Denver.

Ralph B. Lloyd, Western Oil & Gas Association, Los Angeles.

Harry A. Logan, National Petroleum Association, Warren, Pa.

John M. Lovejoy, Seaboard Oil Co. of Delaware, Inc., New York.

H. M. McClure, National Stripper Well Association, Tulsa.

Chas. P. McGaha, National Stripper Well Association, Wichita Falls.

N. C. McGowen, United Gas Pipe Line Co., Shreveport.

B. J. Majewski, Deep Rock Oil Corp., Chicago.

A. C. Mattei, Honolulu Oil Corp., San Francisco.

**Parker L. Melvin*, Pennsylvania Grade Crude Oil Association, Bradford, Pa.

Wm. Moeller, Jr., Southern California Gas Co., Los Angeles.

S. B. Mosher, Signal Oil & Gas Co., Los Angeles.

Henry D. Moyle, Wasatch Oil Refining Co., Salt Lake City.

Burton W. Musser, Utah Oil Refining Co., Salt Lake City.

J. W. Newton, Magnolia Petroleum Co., Beaumont.

I. A. O'Shaughnessy, Globe Oil & Refining Co., St. Paul.

J. R. Parten, Premier Oil Refining Co., Houston.

William T. Payne, American Association of Oilwell Drilling Contractors, Dallas.

A. W. Peake, Standard Oil Co. (Indiana), Chicago.

J. Howard Pew, Sun Oil Co., Philadelphia.

Frank Phillips, Phillips Petroleum Co., Bartlesville, Okla.

E. E. Pyles, Hancock Oil Co., Los Angeles.

E. B. Reeser, Barnsdall Oil Co., Tulsa.

J. French Robinson, East Ohio Gas Co., Cleveland.

W. S. S. Rodgers, The Texas Co., New York.

Chas. F. Roeser, Roeser & Pendleton, Inc., Fort Worth.

Arch H. Rowan, American Association of Oilwell Drilling Contractors, Dallas.

G. L. Rowsey, Gulf Coast Refiners Association, Taylor Tex.

J. D. Sandefer, Jr., National Stripper Well Association, Tulsa.

Edward G. Seubert, Standard Oil Co., (Indiana), Chicago.

R. S. Shannon, Pioneer Oil Corp., Denver.

H. F. Sinclair, Sinclair Oil Corp., New York.

W. G. Skelly, Skelly Oil Co., Tulsa.

Ferd J. Spang, Petroleum Equipment Suppliers Association, Butler, Pa.

Wm. L. Stewart, Jr., Union Oil Co. of California, Los Angeles.

Reese H. Taylor, Union Oil Co. of California, Los Angeles.

H. L. Thatcher, National Council, Independent Petroleum Association, Chattanooga.

Jame W. Vaiden, Natural Gasoline Association of America, Tulsa.

L. Vander Leck, Oil Producers Agency, Los Angeles.

R. van der Woude, Shell Union Oil Corp., New York.

C. P. Watson, Producers' Agency of California, Los Angeles.

Eric V. Weber, Ohio Petroleum Marketers Association, Cincinnati.

Norton H. Weber, National Petroleum Association, Chicago.

A. L. Weil, General Petroleum Co., Los Angeles.

**Phil T. Williams*, National Council of Independent Petroleum Associations, Indianapolis.

Howard J. Whitehill, National Stripper Well Association, Tulsa.

Harry C. Wiess, Humble Oil & Refining Co., Houston.

Robert E. Wilson, Standard Oil Co. (Indiana) Chicago.

Ralph T. Zook, Independent Association of America, Bradford, Pa.

Italics denote former members. Asterisks denote deceased.

PIWC Subcommittees

Economic Advisers

S. P. Coleman, R. W. Meriam, J. E. Pogue, A. Sachs.

Products Conservation Advisers

J. A. Miller, R. Vir Den.

Personnel Subcommittee

B. K. Brown, H. W. Dodge, L. S. Fish, D. R. Knowlton, J. H. Marshall, J. R. Parten, G. F. Prussig.

Pipe-Line-Engineering Subcommittee

C. Bunje, Jr., W. R. Finney, G. J. Hanks, B. E. Hull, C. H. Kountz, T. E. Swigart.

Technical Advisory Subcommittee

M. S. Agruss, J. August, W. N. Axe, E. E. Ayres, E. C. Baldeschwieler, E. S. Bale, J. R. Bates, O. Berg, G. R. Bond, Jr., D. E. Carr, W. E. Chalfant, G. C. Cunningham, D. E. Day, T. G. Delbridge, H. W. Field, J. H. Forrester, A. B. George, D. W. Gould, R. A. Halloran, J. I. Harper, P. J. Harrington, M. J. Hartig, C. E. Headlington, B. J. Heinrich, H. Y. Hyde, E. W. Isom, S. S. Kurtz, H. Levin, W. W. Lowe, K. G. MacKenzie.

XUM

Administrative heads of PAW Foreign Division: A. H. Chapman, W. D. Crampton, J. T. Duce, and C. S. Snodgrass

E. B. McConnell, A. E. Miller, O. N. Miller, W. Miller, R. C. Mithoff, L. W. Moore, E. V. Murphree, W. H. Naylor, T. W. Nelson, B. W. Neumaier, G. G. Oberfell, W. C. Offutt, A. E. Pew, Jr., J. B. Rather, E. P. Ritterhausen, J. K. Roberts, R. F. Robery, W. B. Ross, C. T. Shewell, A. C. Smith, L. Steffens, J. F. M. Taylor, F. D. Tuemmler, G. M. Webb, H. D. Wilde.

Manpower Subcommittee

B. R. Bay, N. C. Beim, H. L. Boyle, G. F. Bush, S. W. Candee, K. R. Dailey, W. A. Delaney, Jr., B. E. Devere, F. D. Dorn, W. L. Felton, C. T. Foster, John Harper, C. H. Hathaway, R. W. Hendee, C. L. Henderson, W. P. Henry, A. E. Johnson, C. A. Johnson, H. W. Jones, R. H. Lackey, Jr., J. J. Leu, H. A. Logan, W. C. Lynch, William Moeller, Jr., Sam Mumma, D. T. Pierce, J. W. Reis, M. H. Robineau, J. F. Robinson, J. P. Rockfellow, K. H. Shaffer, E. J. Sheldon, C. O. Strahley, B. H. Swift, H. L. Thatcher, K. W. Yeates, Howard Zabriskie.

Petroleum Economics Subcommittee

O. A. Ambrose, John Boatwright, G. L. Bonar, J. V. Brown, J. P. Coleman, R. J. Gonzales, D. G. Gray, E. T. Knight, C. M. Lake, H. A. Lapham, J. A. Lentz, Clarel B. Mapes, A. J. McIntosh, J. M. Sands, H. N. F. Schwall, S. A. Swensrud, M. E. Tracey.

Protection of Petroleum Facilities Subcommittee

W. J. Arnold, E. H. Barlow, R. W. Black, P. Campbell, J. D. Day, J. L. Hanna, D. Hogan, P. L. Krauel, W. Moore, A. C. Rubel, F. L. Wallace, L. S. Wescoat, G. O. Wilson.

Products Conservation Subcommittee

B. Armitage, S. M. Birch, A. S. Blank, G. F. Cramer, H. R. Deal, F. L. Frost, G. C. Gibbons, R. M. Gray, J. Huffsmith, H. D. Kline, R. G. Landis, F. H. Marling, L. Moore, W. A. Morgan, W. I. Nunn, C. R. Olson, A. B. Penny, H. Ransford, M. C. Shipley, C. R. Sullivan, J. H. Weiser.

Lubrication and Containers Subcommittee

K. C. Baker, D. P. Clark, C. M. Davison, J. M. Evans, D. G. Hubbard, H. J. Kennedy, F. C. Kerns, J. M. Koch, J. A. Lentz, L. P. Lochridge, H. D. Miller, S. S. Morris, G. L. Neely, J. S. Norris, W. B. Rew, A. L. Weist, L. C. Welch, K. W. Yeates.

Marketing, Automotive and Transportation Subcommittee

J. A. Bruso, E. M. Fitz, L. Huff, F. B. Hufnagel, Jr., G. Laurie, O. Lynch.

Marketing Equipment Subcommittee

C. C. Benedict, B. E. Devere, J. Land, D. O'Connell, W. H. Tell.

Secretaries to Standing Committees

J. V. Brown, L. M. Fanning, L. Laskaris, D. F. Leary, H. F. Parsons, H. P. Reynolds, D. V. Stroop, F. Van Covern, C. A. Young.

Technical Advisory Subcommittees

R. C. Alden, H. A. Ambrose, R. J. Askevold, R. B. Barnes, J. Y. Beach, J. C. Beard, Jr., O. Beech, W. S. Bonnell, W. E. Bradley, P. L. Brandt, R. R. Brattain, W. R. Brode.

F. F. Cleveland, H. G. Cornell, E. Cotton, J. P. Cunningham, L. L. Davis, C. A. Day, Jr., J. C. Dean, C. F. Feuchter, A. P. Frame, A. W. Francis, S. C. Fulton, W. I. Gilbert.

C. E. Hemminger, E. C. Herthel, C. K. Hewes, E. C. Hughes, M. M. Holm, J. B. Hill, C. F. Jones, L. C. Kemp, Jr., R. M. Kennedy, L. N. Leum, B. H. Lincoln, W. H. Litchfield,

C. L. Mateer, E. H. Meier, R. N. Meinert, L. Mittelman, C. W. Montgomery, P. G. Murdoch, M. Neuhaus, J. H. Olehy, D. H. Rank, E. J. Rosenbaum.

W. W. Scheumann, R. F. Schultz, W. H. Shiffler, G. H. Shipley, F. J. Smith, A. F. Spiehler, J. Teter, C. H. Thayer, E. B. Tucker, C. L. Thomas, R. H. Venn, C. K. Viland, C. W. Watson, N. Wright.

War Emergency Pipelines, Inc.

G. F. Brigance, C. Briggs, J. A. Brown, O. R. Burden, B. Cole, R. H. Colley, H. S. Danner, J. F. Drake, T. B. Drum, W. B. Farrar, A. Fraser.

R. W. Gallagher, L. M. Goldsmith, B. I. Graves, J. Hearrell, W. G. Heltzell, H. B. Hensley, H. C. Hervey, A. L. Hooper, R. P. Hopson, A. N. Horne, P. W. Houghtlin, B. E. Hull.

H. V. Johnston, W. A. Jones, E. J. Kennelly, H. T. Klein C. H. Kountz, H. W. Lambert, D. F. Leary, H. J. Lingle, E. C. Link, G. C. Loos.

H. M. McDonald, W. H. McEachern, J. R. Manion, M. Martin, B. K. Morse, J. Norton, K. A. Owen, D. S. Patton, J. H. Pew, H. L. Phillips, F. E. Richardson, C. M. Rosebrugh.

R. C. Sanders, L. F. Scherer, H. F. Sinclair, J. A. Smith, C. E. Stimson, W. H. Stueve, P. T. Thibodaux, C. I. Thompson, S. Westlake, J. M. Williams, P. F. Williams, R. E. Wilson, L. D. Witter, O. Wolfe.

Foreign Operations Committee Members

H. D. Collier, R. H. Colley, J. F. Drake, R. W. Gallagher, H. M. Herron, F. J. Hopwood, W. F. Humphrey, B. R. Jackson, W. A. Jones, P. W. Parker, W. S. S. Rodgers, H. F. Sheets, H. F. Sinclair, R. H. Taylor.

Alternates

J. P. Berkin, M. J. A. Bertin, D. M. Cameron, A. A. Garrabrant, B. I. Graves, C. W. Hamilton, O. Harden, L. B. Levi, J. H. MacGaregill, B. P. Newton, C. E. Olmsted, L. W. Parsons, W. H. Pinckard, H. L. Schultz, E. E. Soubry, A. E. Watts, R. V. Whetsel, A. M. Wylie.

Foreign Operations Committee Members of Subcommittees

C. R. Auster, J. A. Adamson, F. M. Balling, J. P. Berkin, H. R. Berry, H. Bloemgarten, L. K. Blood, R. G. Brown, W. H. Busold, J. R. Callaway, F. S. Campbell, R. W. Carder, J. C. Case, D. M. Cameron, H. Cartwright-Reid, K. F. Coe, S. P. Coleman, W. G. Corwin.

J. A. deLanoy, H. G. Denham, J. T. Duce, W. F. Dunning, A. J. DuPont, H. C. Durrschmidt, R. G. Follis, C. H. Ford, W. G. Foster, E. Fullmer, H. H. Fuller, A. A. Garrabrant, N. Goddard.

W. J. Haley, C. W. Hamilton, D. J. Hanna, H. A. Hassan, E. A. Higgins, D. L. Hooker, F. J. Hopwood, B. R. Jackson, W. H. Koehler, P. K. Kuhne, C. E. Lanning, R. Leibensperger, C. H. Lieb, G. R. Lord, L. P. Lockridge.

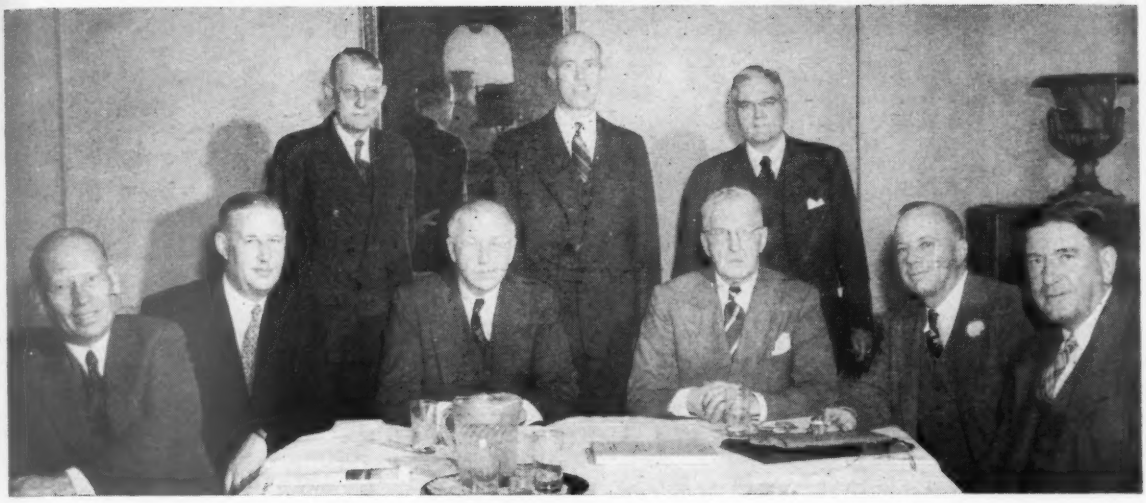
L. F. McCollum, J. P. McCulloch, A. R. McMath, A. M. Martin, B. Mead, G. H. Michler, R. W. Miller, J. B. Middleton, C. S. Morgan, H. B. Malone, B. P. Newton, H. B. Nichols, W. M. O'Connor, G. O'Neal, G. W. Orton.

J. S. Parks, F. C. W. Paton, W. H. Pinckard, F. E. Powell, Jr., J. T. T. Robinson, D. B. Schnabel, R. Schider, F. C. Sealey, R. Siegel, E. A. Skinner, H. E. Slater, O. B. Small, D. G. Smith.

G. H. Taber, Jr., E. R. Thatcher, S. J. Veenstra, A. E. Watts, H. R. Weber, C. Woessner, J. B. Wolston, J. S. Worden.

Staff Personnel

T. G. Benton, C. S. Brewster, J. R. Keith, R. F. Hawkins, A. G. May, B. Mead, J. R. Morris, J. A. Parrish, H. E. Pratt, H. A. Schuler, G. W. Sutton, W. C. Winning.



PIWC Historical Records Committee: Seated—O. D. Donnell, R. I. Graves, J. W. Frey, W. T. Holliday, J. A. Lentz, and Eugene Holman. Standing—L. D. Jurs, G. W. Noble, and G. A. Hill, Jr.

Staff of Petroleum Administration For War, Washington and Districts

Harold L. Ickes, Petroleum Administrator for War
Ralph K. Davies, Deputy Petroleum Administrator
Robert E. Allen, Assistant Deputy Petroleum Administrator
Bruce K. Brown, Assistant Deputy Petroleum Administrator
E. DeGolyer, Assistant Deputy Petroleum Administrator
Robert E. Hardwicke, Assistant Deputy Petroleum Administrator
J. Howard Marshall, Assistant Deputy Petroleum Administrator

Personal Staff of Ralph K. Davies and Assistant Deputy Administrators

M. W. Ball, J. H. Barr, E. E. Batzell, Samuel Botsford, T. L. Crowell, C. J. Deegan, G. E. Dewey, G. M. Drach, L. S. Fish, Wirt Franklin, J. W. Frey, G. M. Fuller, J. P. Getty, S. P. Gorman, R. T. Graham, J. H. Hall, F. H. Harbison, R. E. Haynes, W. D. Hersey, S. E. Hill, Paul Holder, H. C. Ide, Bernard Immerdauer, Bernice Kirschling, G. L. Killion, A. H. Levy, E. W. Littlefield, R. R. McLachlen, Bradley Murray, J. H. Murrell, T. J. Quinn, R. S. Salant, O. M. Smith, J. R. Stark, J. H. Thatcher, Jr., J. E. Thomas, H. C. Turner, K. P. Wirth, Kenneth Woolbert, A. Y. Woodward, G. S. Walden.

Production

W. C. Allen, F. C. Bauchens, P. H. Bohart, G. L. Browne, F. R. Bryan, G. A. Campbell, G. V. Cohee, R. J. Dawson, N. C. Dunbros, H. L. Flood, Joseph Gordon, D. G. Hawthorne, E. J. Heston, V. L. Horner, M. O. Hoffman, I. H. Hughes, R. V. Hughes, K. K. Kimball, D. R. Knowlton, E. R. Lilley, C. B. McClintock, A. C. McColl, Jr., C. R. McKnight, J. R. McWilliams, Linda Miller, M. W. Morris, M. K. Neptune, F. E. Palmer, F. V. L. Patten, E. E. Roth, R. J Schilthuis, C. D. Speed, D. R. Teis, G. H. Vaughn, F. H. Willibrand, Rex Woods, J. J. Zorichak.

Natural Gas and Gasoline

B. C. Adams, Jr., Gordon Cunningham, F. H. Dotterweich, R. W. Ducker, J. F. Gallie, L. E. Heckman, J. H. McCammon, J. W. Martin, J. D. Naftel, Edwin Norman, J. E. Pew, E. H. Poe, P. M. Raigorodsky, P. K. Thompson, C. E. Webber.

Refining

C. H. Alberding, J. T. Akers, W. C. Allinder, A. P. Anderson, T. L. Apjohn, W. R. Argyle, George Armistead, Jr., E. L. Arnold, Jr., D. P. Bailey, Montague Ball, Martin Barbour, B. H. Barnes, K. A. Beach, S. C. Bean, R. R. Bell, O. C. Bergmann, N. E. Birch, W. H. Blank, R. G. Bray, D. G. Brandt, H. W. Butler, P. J. Byrne, Jr., H. D. Chapman, C. S. Cole, Jr., M. B. Cooke, R. M. Cornforth, J. A. Costello, R. B. Cragin, F. T. Craven, Jr., A. B. Culbertson, E. D. Cumming, H. L. Cutler, A. V. Danner, E. A. Dingee, J. W. Donnell, A. C. Dow.

G. F. Eisele, J. H. Elliott, M. Elliott, G. L. Ellis, J. A. Enright, E. W. Evans, F. J. Feely, Jr., M. B. Fitzgerald, D. N. Flann, T. R. Fleck, L. M. Forney, A. L. Foster, R. E. Frambes, A. P. Frame, C. B. Gale, W. W. Gary, H. N. German, George Gibson, L. R. Goldsmith, H. C. Goodman, J. D. Grenke, G. W. Griffith, Jr., J. W. Griswold, F. B. Gummey II, H. G. Hall, G. N. Heller, H. P. Hetzner, J. V. Hightower, E. B. Hjerpe, W. M. Holaday, H. J. Holcomb, H. J. Holdcroft, R. P. Horner, W. A. Howard, J. E. Hughes, M. C. Jacobs, F. M. Jayne, W. O. Jennings, E. O. Jones.

J. E. Kasch, E. E. Kerns, H. F. King, M. J. Kiser, C. M. Lathrop, J. R. Lemmer, I. W. Lloyd, J. W. Loy, H. E. Luffman, E. B. McConnell, W. L. McKinnon, L. A. McVey, F. B. MacKinnon, F. L. Mace, F. H. Magruder, C. A. Mapes, D. M. Masi, Jr., J. W. Mead, William Mendius, M. B. Miller, G. W. Mock, L. A. Monroe, D. L. Neal, C. L. Nichols, C. W. Nofsinger, C. J. Nugent, G. L. Parkhurst, W. E. Perdew, C. B. Petty, G. E. Petty, H. J. Pforzheimer, L. H. Phelps, Jr., F. J. Phillippbar.

L. E. Reark, Raymond Reuter, R. F. Riddle, C. M. Ridgway, P. M. Robinson, E. S. Ross, J. E. Rouse, R. H. Rudrauff, B. M. Scofield, F. E. Shelly, V. E. Sicks, G. H. Skerritt, F. B. Slagle, C. R. Smith, D. A. Smith, R. C. Smith, R. L. Speer, H. A. Stiles, K. L. Stone, B. W. Story, P. C. Stratton, L. L. Sweet, Q. B. Taggart, Anthony Tedesco, O. J. Thompson, C. R. Wagner, J. F. Walter, W. E. Wanner, J. M. Waters, Whitney Weinrich, R. F. Wellman, D. G. Welsh, Reuben Werlin, A. J. Wesh, B. K. Wherry, W. W. White, S. Wilk, D. O. Wilkes, D. W. Wilson, F. G. Wilson, J. R. Wilson, R. P. Wilson.

Supply and Transportation

P. G. Anderson, S. D. Archbold, H. L. Armstrong, H. S. Austin, E. C. Baker, D. H. Barrow, H. A. Birch, Jr., W. P. Blanchard, J. E. Boice, P. B. Bolian, F. C. Boop, A. K. Brankamp, F. I. Brinegar, Donelson Caffery, H. D. Carter, B. C. Clardy, F. C. Colegrove, L. R. Cowles, L. F. Craig, V. S. Curry, T. M. Dailey, Jr., J. H. Demmel, E. G. Denniston, P. D. Fell, W. A. Fisher, A. W. Gee, H. A. Gilbert, H. E. Hassett, R. A. Heller, H. M Hipple, D. B. Hodges, G. G. Horton, E. B Juliber, R. K. Kelly, W. C. Kinsolving.

W. R. Lange, J. W. Liddell, C. L. Lockett, Jr., S. H. Low, C. H. Lundt, J. F. McCarthy, C. A. McCollum, W. H. McEachern, R. B. McLaughlin, H. T. Mather, L. P. Mayeskie, H. J. Miller, R. L. Minckler, J. P. Mitchell, J. T. Morgan, T. H. Norris, W. L. Ogden, J. R. Parten, R. L. Perry, R. W. Phillips, R. C. Sauer, D. F. Sears, P. H. Shepherd, D. E. Shoemaker, L. A. Smith, C. M. Southern, C. H. Wager, F. H. Warren, Earl Whatley, C. H. Whitman, M. L. Wilcox, Boyd Wilson, G. A. Wilson, J. A. Winterberger.

Marketing

L. H. Albright, D. C. Arnold, R. M. Balch, Jr., H. J. Barton, P. A. Best, G. L. Campbell, B. H. Clary, R. T. Collier, A. I. Colbert, Stanley Colter, M. A. Combs, Herbert Coons, Howard Cooper,

XUM

Facilities Protection Committee of PIWC: Seated—H. D. Collier, R. H. Cunningham, C. V. Broadley, Col. J. Frank Drake, W. D. Mason, Philip Bastedo, D. V. Stroop, G. A. Hill, Jr., J. Howard Pew, Eugene Holman, W. G. Skelly, C. L. Henderson, J. R. Day, Adm. J. V. Parker. Standing—Maj. F. R. Wilder, N. C.McGowen, Frank Campbell, and J. C. Hunter

W. F. Courtney, G. J. Coy, Jr., Kenneth Darling, J. H. Dockendorff, J. M. Doherty, Isaac Doughton III, John Downing, Kenneth Dunbar, J. H. Ellender, J. P. Ervin, H. G. Fowler, H. M. Fraser, C. E. Golden, C. W. Grenz, J. A. Hammer, W. C. Harpster, Walter Hochuli, A. J. Hocking.

Melville Keim, N. C. Keith, N. L. Klein, R. G. Landis, J. L. Lempert, Jr., W. C. M. Lessing, R. A. Ludlaw, J. E. K. MacLoane, R. W. MacMillan, G. G. Martinson, R. R. Matthews, J. E. Mayo, J. D. Meyer, T. C. Mitchell, C. B. Moore, C. C. Moore, J. F. Payne, A. W. Roth, P. J. Ryan, L. V. Shaughnessy, W. D. Sherman, F. P. Smith, Jr., I. C. Tarler, H. H. Wends, Carl Wennblad, R. M. Wilkinson, E. K. Williams, R. D. Williamson, R. O. Wilson, J. S. Wyatt, F. Zengel.

Materials

W. E. Batchellor, J. L. Beatty, Jr., R. R. Bickman, E. H. Bishop, H. E. Bovay, Jr., L. W. Breyfogle, W. C. Brooks, W. H. Butler, G. W. Cale, J. W. Carroll, G. M. Carter, Jr., W. L. Clark, W. H. Collins, L. F. Connell, P. E. Conner, B. F. Conwell, Joseph Decaro, E. H. Dipple, Edward Edwards, J. E. Eldridge, Hudson Emery, J. D. Fenton, L. C. Ferguson, E. J. Fitzgibbon, P. E. Griffin, J. R. Guynes, G. W. Hamilton, H. R. Hansen, I. G. Harmon, S. F. Hatch, G. T. Haymes, L. L. Horstman, P. F. Houserman, W. F. Huff, C. J. Illig, B. A. Irwin, H. W. Johnson.

H. M. Kent, G. W. Knoth, J. A. Kunkel, E. C. Leeves, Jr., H. I. Lieberman, H. E. Lowery, P. K. Lyle, Meade McCamey, J. H. McCarty, R. McKinless, T. A. Manning, A. A. Nelson, A. W. Novak, G. W. Orton, M. H. Parks, C. P. Parsons, K. O. Peters, M. M. Plumb, W. C. Pyeatt, G. B. Reese, C. W. Riley, E. E. Robbins, S. I. Rogers, D. K. Rosenthal, S. H. Schwinge, B. W. Shields, O. L. Shook, G. T. Short, W. C. Smiley, S. L. Stentz, E. L. Struwe, R. K. Tallant, E. R. Thatcher, J. H. Thompson, J. G. Townley, D. L. Trax, Lawrence Von Bulow, B. A. Warren, F. A. Watts, G. A. Weeks, Alonzo Welborn, R. A. Wimmer, C. E. Yeagley, J. R. Young, Alvin Zwerneman.

Program Planning Division

J. A. Cogan, S. P. Coleman, J. F. Curtin, C. J. Deegan, C. W. Furcht, G. R. Hopkins, C. D. Maxutov, H. W. Page, W. G. Webner.

Foreign

J. G. Allen, W. C. Asbury, H. V. Atwell, Novel Baker, E. L. Baldeschwieler, G. T. Ballou, G. S. Bays, Jr., G. A. Bell, Arne Blyberg, Harold Bottemley, A. O. Boyer, D. E. Brannerman, P. M. Buttermore, M. C. Case, A. H. Chapman, J. F. Conway, Ernest Cotton, W. P. Cox, W. D. Crampton, C. A. Daldy, J. G. Detwiler, Albert Ditson, F. P. Donohue, G. E. Dorsey, J. T. Duce, H. B. Dunn, L. P. Evans, W. F. Farragher, E. H. Finch, J. W. Flanagan, D. S. Fraser, H. L. Freeman, W. C. Frysinger.

A. R. Gano, J. L. Gates, M. J. Gavin, C. H. Gerdes, J. F. Griffis, D. F. Gunby, Valdimir Haensel, E. C. Hannum, E. W. Hard, H. A. Hassan, R. F. Hawkins, W. B. Heroy, J. L. Herschbach, V. M. Hodge, M. A. Huffman, F. G. Jackson, F. O. Jackson, B. F. Johnson, J. P. Jones, Bertram Killens, G. W. Knight, E. K. Knowlton, J. D. Kurtz, H. R. Lai-Sun, C. M. McCall, C. H. McDaniel, A. N. Mackenzie, B. L. MacKusick, H. C. MacWhinnie, M. R. Mandelbaum, C. U. Marks, A. R. J. Marsden, L. A. Mekler, W. T. Meyer, L. M. Miller, P. W. Miller, E. S. Mills, D. A. Morgan.

F. B. Notestein, L. H. Nuland, R. W. Olinger, R. E. Parkhurst, J. A. Pirnie, J. C. Poulton, O. G. Pratt, Grover Rees, F. Reeves, I. V. ReHill, E. H. Reichl, J. L. Rich, B. E. Roetheli, G. M. Ruby, R. A. Schilling, Hans Schindler, G. A. Shaner, P. W. Sherwood, A. K. Smith, O. B. Smart, C. S. Snodgrass, W. D. Sorrells, Maxwell Stevenson, R. W. Stiles, Lewis Swallow, C. P. Thompson, E. F. D. Von Voss, H. M. Weir, H. C. White, R. R. Wiggins, E. H. Wilson, R. A. Wrightman, G. W. Young, Jr.

Public Relations

H. W. Arndt, R. R. Burkhardt, J. G. Colligan, K. E. Cook, A. R. Corsini, J. M. Freund, E. J. Haffel, L. H. Hollenbeck, S. B. Jackson, J. F. Kelly, E. B. Lyman, Gerald Miller, H. S. Mullany, B. H. Pearse, A. J. Rabe, L. R. Richardson, S. W. Robinson, G. W. Smith, W. O. Somin, P. C. Woodbridge, H. A. Yocom, C. J. Deegan, G. M. Sessions.

Facilities Security

A. A. Jergins, W. K. McCoy, W. D. Mason, A. C. Sommers.

Research

O. S. Ambrose, Katharine Carman, J. C. Casper, J. F. Klar, C. D. Lockwood, R. G. McCabe, R. M. Murphy, E. B. Swanson, E. A. Wye, Jr.

Legal

W. E. Avery, J. E. Bartley, W. B. Browder, Jr., C. A. Case, Jr., H. P. Crawford, R. P. Edmunds, R. N. Freed, R. E. Friedman, R. E. Hardwicke, D. M. Hudson, J. F. Jones, W. P. Keeton, Mortimer Kline, J. F. Leonard, Robert Mandel, R. E. Morgan, W. T. Pheiffer, William Scully, Webb Shadle, W. L. Summers, O. E. Swan, Jr., J. R. Wolf.

PAW—District 1

Administrative

J. D. Collins, H. W. Dodge, O. L. Gregory, Jr., B. J. Lane, A. Levine, L. V. Roberts, H. J. Rodriguez, S. Thompson, S. B. Wilkes.

Production

V. F. Bowyer, C. C. Coffman, H. W. Fuellhart, H. E. Stocking, J. R. Wylie, Jr.

Natural Gas and Gasoline

F. M. Brewster, R. S. Hyde.

Refining

C. J. Everett, E. H. Kares, A. H. Ketchum, G. H. Mettam, F. M. Miller, W. Naden, D. D. Nash, H. Sydnor, H. A. Tarantous.

Supply and Transportation

P. J. Butler, E. H. Cleaveland, W. C. Eberle, H. Graham, R. R. Hooper, J. P. Patterson, J. B. Snodgrass, G. R. Torborg, P. B. Watson.

Foreign

L. L. Anderson, E. L. Baldeschwieler, E. M. Butterworth, W. A. Horne, P. K. Kuhne, J. D. Murch, H. M. Noel, B. E. Roetheli, N. G. Wood.

Facilities Security

D. W. Broome, A. H. Cole, E. C. Eastman, F. A. Epps, G. W. Gardner, C. H. Haupt, R. S. Lowe, E. A. Orpin, F. S. Proctor, R. L. Smith.

Marketing

M. Anton, W. C. Asbury, F. T. Bailey, W. J. Baldwin, Jr., P. F. Becker, A. C. Beningson, G. A. Bittner, W. R. Black, J. O. Blakely, J. R. Brannan, T. J. Burke, C. A. Campbell, R. H. Coven.

L. B. Davis, J. F. Downey, J. E. Dozier, H. T. Evans, J. P. Fenton, E. W. Ford, N. F. Foulds, E. S. Friend, A. Golden, W. G. Heinze, D. E. Henneberry, W. M. Horigan, R. J. Hull, F. T. Johnson, G. J. Kelly, R. T. McComas, T. F. McGarey, R. McTarnahan, F. B. Miller, D. M. Minton, H. F. Muth.

G. C. Oswald, E. E. Overton, F. J. Parks, J. C. Pastor, F. W. Potter, R. Prouty, W. P. Schenck, A. F. Schoenharr, J. H. Schoonmaker, C. S. Sichel, E. A. Smith, L. R. Snyder, T. J. Spellman, E. M. Terhune, L. A. Torraca, H. B. Van Clevel, G. N. Walker, J. Williamson, A. B. Wolle.

Public Relations

C. E. Allen, P. E. Bird, W. W. Burns, H. R. Corsini, W. C. Daffron, E. W. Esmay.

Materials

R. M. Dinges, A. W. Schillinger, G. F. Will.

PAW—District 2

Administrative

P. D. Denton, W. F. Franklin, I. E. Lamp, C. K. Schwartz, W. W. Vandeveer.

Production

C. C. Brown, W. F. Brown, J. Cannon, G. D. Chastain, G. Grimes, H. E. Gross, M. R. Joy, R. B. Kelly, R. E. Koller, M. Lee, D. M. Logan, M. S. Loy, R. W. Melhorn, R. B. Newcombe, Jr., K. M. Probst, H. L. Wadsworth, J. E. Washington, H. L. Williford.

Natural Gas and Gasoline

J. K. Finlayson, S. W. Herndon, H. O. Orton, M. S. Patton, J. F. Swab.

Refining

F. J. Mack, E. H. Reichl.

Supply and Transportation

P. J. Bond, W. DuMont, E. J. Frueh, M. Kirkpatrick, R. E. Travis, J. A. Turner.

Marketing

J. E. Anderlik, R. M. Balch, Jr., E. L. Bride, H. Christianson, M. C. Dean, H. A. DeBaufer, R. E. Fitzgerald, O. P. Hansen, R. L. Harper, D. J. Hayes, E. L. Hughes, C. W. Johnson, R. E. Johnson, R. Jones, H. C. Lewis, M. L. Long, F. K. Meyer, W. L. Miller, H. W. Nankervis, J. C. O'Connor, G. M. Orr, E. A. Salo, F. Schutt, C. O. Staley, L. B. Sullivan, E. F. Underwood, J. C. Veltman, E. A. Weil, D. W. Williams, G. B. Williams.

Materials

J. F. Barling, T. Bishop, S. R. Clinkscales, H. L. Dickson, J. P. Harper, L. B. Holland, H. V. Klug, B. F. Koepke.

Facilities Security

S. H. Anderson, G. J. Collins, C. P. Holmes, R. C. Mitchell.

PAW—District 3

Administrative

W. M. Averill, D. E. Buchanan, D. E. Cornell, W. J. Murray, Jr., M. A. Rutis.

Production

J. B. Best, E. R. Brann, E. O. Buck, R. L. Carruthers, J. J. Doyle, A. B. Gibson, L. W. Hewitt, G. O. Ives, B. G. Martin, A. Moore, C. Schnurr, E. A. Wahlstrom, L. J. Wilson.

Natural Gas and Gasoline

H. M. Brown, J. H. Graham, G. E. McKay, M. L. Mayfield, L. L. Mistror, W. D. Morris, A. R. Taylor.

Refining

M. N. Bush, G. T. Granger, F. W. Hall, J. M. McMillan, D. P. Sturges.

Supply and Transportation

W. E. Averill, D. G. Gray, T. D. Henley, H. Lyendecker.

Marketing

S. W. Burr, E. J. Dorgan, Jr., A. P. Dyer, Jr., W. R. Mook, Jr., G. P. Thompson.

Materials

J. A. Bonham, R. E. Clark, R. L. Cochran, T. P. Drummond, S. H. Harper, F. L. Hereford, C. E. Naylor, H. A. Rankin, J. A. Rowe, J. B. Thompson, F. M. Tyler.

Facilities Security

H. E. Boysen, K. Earhart, D. J. Kraeger, D. T. Parker, G. Sawtelle.

PAW—District 4

Production

J. R. Fanshawe, A. W. Weeks, C. Wegemann, J. J. Zorichak, M. J. Foley.

Natural Gas and Gasoline

A. M. Ballard, P. K. Sticelbar.

Refining

E. A. Markey, R. N. Sears.

Marketing

F. C. Brooks, W. K. Phillips, H. T. Rapp, C. W. Theal, L. S. Waite, L. G. Wilke, W. Yeates.

Materials

C. Clymer, J. B. Schuyler.

PAW—District 5

Administrative

W. D. Foote, C. Thomas.

Production

C. Beal, E. L. Davis, A. I. Gregorsen, E. Jussen, W. Kleiman, C. L. Moore, A. E. Morphy, W. H. Osgood, L. M. Pearson, T. A. Pollard, W. W. Porter, K. L. Reynolds, J. R. Thomas, E. G. Trostel, L. Vander Leck, R. G. Whealton.

Natural Gas and Gasoline

E. A. Galvin.

Refining

V. W. Balzer, D. W. Boardman, E. W. Gard, G. F. Prussig, M. P. Youker.

Supply and Transportation

W. L. Bagby, H. B. Fairchild, A. C. Saul, J. K. Steele.

Marketing

H. E. Britzman, W. H. Cotrel, C. E. Heyns, J. C. Keesling, N. J. McPhail, A. V. Stoneman.

Materials

E. E. Cater, C. T. Reichert.

Facilities Security

J. R. Eidom, O. D. Pettit.

District 1 Advisory Committees

General Committee

J. A. Brown, J. W. Carnes, R. H. Colley, S. B. Eckert, B. I. Graves, W. S. Hallanan, B. B. Jennings, W. A. Jones, F. J. Robinson.

Marketing and Distribution Committee

A. C. Bedford, J. Blaustein, J. W. Carnes, J. D. Collins, H. W. Dodge, J. Downing, J. E. Dyer, S. B. Eckert, W. L. Faust, W. V. Hartman, R. T. Haslam, M. H. Hindman, J. A. Kelly, W. H. Kershaw, R. T. Kittinger, W. Moore, O. D. Robinson, A. W. Rowe, J. W. Scott, W. G. Violette, J. F. White, M. B. Whiting, W. Yeager.

Production Committee

H. P. Barton, W. J. Brundred, P. H. Curry, F. Dorn, J. Glass, W. S. Hallanan, G. J. Hanks, G. W. Holbrook, C. C. Hogg, P. Melvin, D. T. Ring, R. A. Startzman, L. L. Tonkin, R. T. Zook.

Natural-Gas and Gasoline Committee

S. J. Brendel, H. D. Freeland, D. P. Harston, D. S. Keenan, T. H. Kerr, W. A. Naumers, R. N. Parks, J. F. Robinson, L. L. Tonkin, H. A. Wallace, Jr., G. E. Welker.

Refining Committee

C. R. Barton, W. F. Burt, H. S. Chase, R. H. Colley, J. S. Cordell, A. D. David, J. B. Fisher, M. W. Lowe, A. E. Pew, Jr., W. A. Slater, C. F. Smith, D. J. Smith, G. H. Tabor, Jr., R. E. Wilson, W. S. Zehrung.

Supply and Transportation Committee

J. F. Drake, W. R. Finney, B. I. Graves, R. R. Griffin, W. A. Jones, R. A. Keck, H. T. Klein, C. H. Kunze, H. A. Logan, W. M. McEldowney, R. M. Parker, Jr., J. P. Patterson, A. W. Rowe, H. G. Schad, D. J. Smith, R. C. Tuttle, H. B. Van Clevel, A. E. Watts, J. F. White, F. C. Wright, S. B. Wright.

General Statistical Subcommittee

J. Baney, J. E. Dyer, C. J. Everett, R. W. Reinhart, H. Schwall, F. M. Surface.

General Materials Subcommittee

R. B. Anderson, C. C. Benedict, L. V. Boggs, R. J. Cooper, C. H. Ehlers, G. J. Hanks, R. S. Hatch, A. J. Kelly, H. B. Malone, J. M. Post, D. T. Ring.

Barge Subcommittee

H. S. Atchison, W. C. Eberle, T. J. Heath, T. D. Hooper, R. Kelley, R. B. Mitchell, Jr., J. P. Patterson, T. A. Sposato, S. Tonner, W. F. Toomey, F. H. Tresher, P. S. Wise.

Tank-Car Subcommittee

C. F. Dowd, H. C. Hoffa, A. C. Hultgren, J. M. O'Day, A. G. Phelps, H. G. Schad, E. D. Sheffe, R. J. Walshe, F. C. Wright.

Tankers Subcommittee

T. E. Buchanan, J. F. Drake, R. R. Griffin, B. B. Howard, C. H. Kunze, A. E. Watts.

Transport Trucking Subcommittee

C. C. Benedict, K. J. Eisenhardt, A. C. Hultgren, G. Laurie, W. M. McEldowney, R. H. Maupin, H. I. Moul, F. P. Mutrie, S. F. Niness, J. M. O'Day, L. A. Odom, A. G. Phelps, H. A. Pillars, E. D. Sheffe.

Pipe-Line Subcommittee

P. R. Applegate, W. R. Finney, L. M. Goldsmith, G. J. Hanks, C. H. Kountz, D. J. Smith.

Transportation Supply Subcommittee

W. M. V. Ash, E. F. Brakefield, G. Currie, H. N. Emerson, F. W. Garnjost, R. A. Hunter, R. A. Keck, J. L. Keener, A. C. Marino, R. M. Parker, Jr., W. F. Roth, C. J. Skidmore, A. E. Watts.

Extra Transportation Expense Managing Subcommittee

P. A. Brawley, E. C. Breeding, E. M. Callis, J. F. Drake, B. I. Graves, J. W. Pegg, H. V. Peterson, W. R. Reitz, O. D. Robinson, H. G. Schad, D. J. Smith, A. E. Watts.

Refining Materials Subcommittee

C. R. Auster, C. P. Barton, H. S. Chase, W. W. Gamble, G. T. Haymes, M. Houston, J. J. Mack, H. M. Nichols, W. H. Price, W. Samans, T. D. Tifft.

Refinery Costs Subcommittee

W. F. Burt, A. E. Pew Jr., C. F. Smith, G. H. Taber, Jr.

Refinery Specifications Subcommittee

J. R. Bates, H. E. Bloomsburg, L. C. Derbyshire, H. G. M. Fischer, A. P. Frame, G. H. Freyermouth, H. M. Hancock, T. J. Harkins, J. Kuhne, J. T. McCoy, L. W. Moore, J. B. Rather, C. T. Reinhardt, W. A. Slater A. Skiolvig, J. S. Worden.

Refinery Operations Subcommittee

J. R. Bates, L. M. Bound, H. G. Burks, Jr., W. F. Burt, L. W. Doolan, C. B. Duke, D. L. Hooker, P. K. Kuhne, R. J. Self, W. A. Slater, C. F. Smith, W. F. Stroud, G. H. Taber, Jr.

XUM

Butadiene and Ethylene Subcommittee

J. E. Hoopes, R. M. Landon, J. T. McCoy, A. E. Pew, Jr., H. R. Poland, D. T. Shaw.

Aviation-Gasoline Subcommittee

H. G. Burks, H. W. Field, D. W. Grant, J. R. Hawes, J. B. Hill, R. M. Landon, T. W. Moore, J. B. Rather, C. E. Smith.

Manpower Subcommittee

B. E. Heath, G. B. Hunter, R. L. Mason, W. H. Zabriski,

Minimum Stocks Subcommittee

J. C. Grew, G. B. Hunter, D. Lincoln, G. H. Taber, Jr., W. F. Thiede.

Asphalt Subcommittee

G. R. Christie, J. A. Feely, F. R. Field, R. C. Heath, J. S. Helm, W. W. McFarland, H. Smith, D. Waxman, F. V. Widger, J. P. Williams.

Advertising Subcommittee

S. M. Birch, H. F. Brown, F. S. Cannan, H. L. Curtis, J. J. Delaney, F. R. Frost, R. M. Gray, E. Griffiths, D. S. Marschner, J. A. Miller.

Cost and Price Adjustment Subcommittee

E. M. Callis, H. W. Chapin, H. Curtain, M. Dietshe, O. H. Gundlach, E. A. Heiss, W. A. Heldman, L. J. Rosenfeld.

Containers Subcommittee

D. Clark, W. H. Correa, H. O. Deusch, J. B. Fisher, D. E. Hoffman, F. C. Kerns, J. M. Koch, L. P. Lochridge, P. D. McKay, E. D. Moncrieff, W. M. Schmidt, F. J. Snyder, J. H. Yater.

Equipment Subcommittee

C. C. Benedict, G. E. Bubar, W. A. Courtenay, O. H. Gundlach, H. W. Holland, R. Rogers, H. S. Tait.

Manpower Subcommittee

A. C. Bedford, W. C. Burns, C. M. Gile, C. F. Hatmaker, J. M. Koch, J. M. Patterson, W. G. Violette, S. B. Wright.

Fuel Oil Subcommittee

R. M. Bartlett, E. M. Callis, J. W. Connolly, C. H. Fay, L. B. Fox, H. H. Fuller, J. L. Minner, J. J. Mulvey, H. L. Schwartz, J. W. Scott.

District 2 Advisory Committees

General Committee

K. S. Adams, B. R. Bay, Paul G. Blazer, O. D. Donnell, Harold B. Fell, B. L. Majewski, A. W. Peake, F. Phillips, E. G. Seubert.

Production Committee

K. S. Adams, W. B. Emery, H. B. Fell, R. J. Hall, R. F. Hamilton, C. C. Herndon, A. U. McCandless, H. M. McClure, H. N. Pardee, R. J. Pryor, A. S. Ritchie, O. C. Schorp, C. T. Smith, H. M. Stalcup, E. D. Wallace.

Refining Committee

P. G. Blazer, R. J. Black, R. Brazell, H. W. Camp, G. W. Hanneken, C. L. Henderson, F. H. Holmes, R. R. Irwin, John D. King, W. Miller, I. A. O'Shaughnessy, M. G. Paulus, J. F. M. Taylor.

Natural Gas and Gasoline Committee

A. W. Ambrose, B. R. Bay, G. R. Benz, J. Bowes, E. Buddrus, E. V. Kesinger, J. A. LaFortune, A. M. Rippel, C. S. Sanders, H. M. Stalcup, T. J. Strickler, W. C. Taggart, J. W. Vaiden.

Distribution and Marketing Committee

H. T. Ashton, A. Ball, H. A. Cowden, R. E. Decker, D. O. Groce, L. Harms, A. M. Hughes, H. J. Kennedy, R. R. Kibbe, P. E. Lakin, R. F. McConnell, R. W. McDowell, B. L. Majewski, A. C. Sailstad, A. A. Stambaugh, H. M. Tartt, C. B. Watson, P. T. Williams.

Transportation Committee

C. Bunje, Jr., L. E. Harmon, G. R. Kitner, C. H. Kountz, H. L. McReynolds, H. Moreland, C. H. Musgrave, A. W. Peake, L. H. Pritchard, E. G. Seubert, L. A. Snyder, S. A. Swensrud, O. Wanek, W. W. Vandeveer.

Supply and Transportation Committee

R. Brazell, W. H. Holmgren, D. D. Irwin, C. H. Kountz, H. L. McReynolds, B. L. Meece, C. R. Musgrave, J. L. Nolan, A. M. Ottignon, A. W. Peake, C. A. Prichard, A. C. Sailstad, R. K. Schoolroy, E. G. Seubert, E. E. Smith, L. A. Snyder, S. A. Swensrud, W. M. Vandeveer, O. Wanek, Jr., J. A. Winger.

Joint Great Lakes Subcommittee

A. L. Christy, S. Clark, C. H. Ebert, A. W. Frey, R. R. Mitchell, W. H. Moegelin, L. S. Ruwe, E. L. Stauffacher, R. R. Tilton, G. C. Wagener, O. Wanek, Jr., P. S. Wise.

Joint Barge Subcommittee

M. C. Dupree, A. W. Frey, J. W. Hershey, H. L. McReynolds, W. H. Moegelin, W. W. Tennant, P. S. Wise.

Joint Tank Car Subcommittee

J. A. Bruso, A. D. Carleson, C. F. Dowd, B. C. Graves, J. P. Gudger, A. C. Hultgren, G. McCabe, C. R. Musgrave, R. T. Musser, W. O. Narry, D. Orme, C. D. Ruth.

Materials Subcommittee

W. M. Bovaird, E. A. Brown, W. H. Creel, H. W. Ladd, J. A. LaFortune, A. W. McKinney, H. M. McClure, H. N. Pardee, W. W. Reed, J. L. Shakely, L. C. Welch.

Crude-Oil Supply Subcommittee

R. G. Arner, H. T. Ashton, R. Brazell, H. W. Camp, S. H. Elliott, M. E. Foster, A. P. Ruether, G. W. Sanders, L. T. Weger, F. Wood, G. G. Woodruff.

Statistical Subcommittee

J. E. Arens, J. W. Boatright, R. Brazell, J. C. Day, R. R. Irwin, A. C. Sailstad, J. M. Sands, S. A. Swensrud.

Refining Technical Subcommittees

R. C. Alden, C. M. Alexander, R. W. Boyd, R. Brazell, G. Burrus, H. W. Camp, L. S. Cannon, F. C. Cutting, F. A. Deering, V. I. Downey, H. P. Ferguson, M. M. Fisher, J. H. Forrester, M. E. Foster, B. C. Frichot, W. R. Graham, W. S. Gullette, W. G. Hiatt, F. B. Koontz, R. M. Landon, J. P. Langfitt, B. H. Lincoln, W. H. Litchfield, R. E. Luton, E. B. McConnell, F. W. McCurry, C. L. Mayhall, R. E. Miller, W. Miller, W. E. Moody, V. R. Oakley, A. R. Patterson, A. E. Pew, Jr., J. S. Pfarr, E. B. Phillips, E. W. Potter, J. B. Rather, J. K. Roberts, T. H. Rogers, W. Scheuman, A. Skiolvig, A. F. Spiehler, J. O. Thoen, W. L. Thompson, J. W. Vaiden, J. White, J. A. Witherspoon, G. G. Woodruff.

Asphalt Subcommittee

C. W. Barbour, D. R. Donlen, P. C. Doyle, B. Ennis, D. H. Jenks, Jr., I. W. Lloyd, H. G. Nevitt, G. Nix, H. L. Tilton, R. F. Trumbull.

Grease Manufacturers Subcommittee

J. R. Battenfeld, S. Bevin, E. Caddock, C. C. Huffman, H. J. Kennedy, W. H. Oldacre, W. H. Saunders, Jr.

Lube Oil Compounders Subcommittee

K. C. Baker, T. R. Garrett, A. J. Hedlund, M. M. McArthur, R. W. McDowell, J. L. Nolan, D. T. Riley, B. G. Shepard.

Containers Subcommittee

K. C. Baker, M. R. Bower, J. C. Day, H. J. Kennedy, M. M. McArthur, R. W. McDowell, W. M. Murray, J. L. Nolan, D. B. Pruess, C. W. Snider, L. C. Welch.

Manpower Subcommittees

H. T. Ashton, N. C. Beim, O. E. Bransky, H. A. Brown, A. S. Chamberlain, H. W. Crawford, F. C. Cutting, F. A. Deering, R. A. Helling, A. M. Hovlid, P. R. Kempf, L. E. Kincannon, R. E. Luton, R. W. McDowell, J. L. Nolan, I. A. O'Shaughnessy, S. H. Reed, J. W. Rees, W. E. Slaughter, Jr., A. A. Stambaugh, R. S. Stewart, G. E. Tappan, E. J. Webster, N. L. White, P. T. Williams.

Joint Use of Facilities Production Subcommittee

J. A. Aylward, W. B. Emery, J. W. Jordan, R. B. Kelly, H. M. McClure, H. N. Pardee, T. L. Regan, O. C. Schorp, H. N. Stalcup.

Joint Use of Facilities Natural Gas and Gasoline Subcommittee

A. W. Ambrose, C. U. Daniels, J. H. Dyer, E. V. Kesinger, J. A. LaFortune, T. J. Strickler, W. C. Taggart.

Miscellaneous Marketing Subcommittees

H. T. Ashton, A. L. Bailey, G. Baldwin, A. Ball, C. E. Bauer, C. H. Becker, N. C. Beim, A. Boyd, D. Brown, C. Brewer, S. M. Burnap, W. J. Carthaus, E. C. Campbell, E. T. Clark, L. S. Corbin, L. L. Corydell, Jr., R. J. Coughlin, H. A. Cowden, P. Deer, J. L. Dryer, L. M. Faber, J. E. Fehsenfeld, A. Feldman, H. K. Franklin, H. L. Gardner, A. C. Godward, D. O. Groce, W. R. Haggart, L. L. Harms, H. D. Hines, B. Holm, T. J. Hudson, A. M. Hughes, A. H. Jensen, W. I. Johnson, P. R. Kempf, H. J. Kennedy, R. Kent, P. E. Lakin, G. Lilly, R. F. McConnell, R. W. McDowell, S. H. Maas, J. Marshall, H. T. Martin, W. R. Mason, R. L. Meece, A. Merila, W. H. Merritt, J. I. Nolan, W. I. Nunn, N. H. Ott, R. P. Peck, B. M. Provis, R. D. Rankin, B. S. Reid, C. S. Rosenthal, G. W. Runyan, W. F. Schierholz, D. W. Shaw, W. H. Shidaker, P. Siteman, A. J. Smaby, H. W. Smoots, F. E. Spencer, A. A. Stambaugh, R. M. Stith, H. Sucher, A. H. Sus, H. G. Swanson, W. H. Tell, R. Updike, M. W. Voluntine, D. Warning, C. B. Watson, E. J. Webster, J. Wilbur, P. T. Williams, G. G. Woodruff.

General Committee Staff

J. E. Arens, W. Balog, W. D. Baskett, Jr., E. W. Bergstrom, J. E. Boudler, C. P. Cleary, E. R. Comer, R. Edmonds, M. E. Foster, E. J. Frueh, G. L. Gardner, R. C. Glacel, W. A. Goes, R. Hamilton, L. E. Harmon, H. K. Helvie, R. W. Hoffman, G. C. Jehle, L. F. McCullem, H. Mueller, C. R. Musgrave, F. B. Neptune, S. P. Nunley, E. M. Peterson, G. P. Rada, A. C. Sailstad, H. M. Tartt, H. Wilcox, J. A. Winger, L. T. Weger, H. H. West.

District 3 Advisory Committees

General Committee

G. A Hill, Jr., R. B. Jones, J. S. Leach, N. C. McGowen, J. W. Newton, C. F. Roeser, and H. C. Wiess.

Production Committee

J. S. Abercrombie, T. H. Barton, J. S. Bridwell, D. H. Byrd, D. Frame, B. A. Hardey, G. A. Hill, Jr., J. C. Hunter, T. M. Martin, S. W. Richardson, J. H. Russell, A. A. Seeligson, J. R. Suman, and V. S. Welch.

Refining Committee

J. S. Allen, M. E. Baish, H. H. Baker, B. H. Barnes, K. W. Bartlett, M. W. Boyer, F. P. Dodge, D. P. Hamilton, F. E. Holsten, P. E. Hurley, P. Kendall, W. W. Lechner, J. W. Newton, M. J. Rathbone, J. M. Thompson, R. Tollett, and R. H. Waser.

Natural Gas and Gasoline Committee

L. Abramson, Jr., C. H. Alexander, J. H. Boyle, J. H. Dunn, T. R. Goebel, L. E. Hagy, D. W. Harris, P. Kayser, N. C. McGowen, C. P. Rather, E. F. Schmidt, and R. E. Wertz.

Supply and Transportation Committee

A. L. Christy, C. Fitzgerald, B. Hull, E. C. Kincade, W. T. Knight, J. L. Latimer, J. S. Leach, R. B. McLaughlin, M. Nixon, R. W. Pack, J. R. Parten, F. E. Richardson, G. L. Rowsey, T. E. Swigart, E. R. Turner, H. C. Wiess, and J. H. Wood, Jr.

Distribution and Marketing Committee

R. B. Anderson, C. B. Barrett, A. F. Buck, O. H. Carlisle, T. M. Gordon, H. L. Hathaway, M. Houghland, R. B. Jones, H. S. Lane, J. S. Leach, R. G. McIntyre, G. Miller, O. E. Mitchell, A. F. Reed, E. H. Simpson, E. H. Todd, J. B. Turner, and L. S. Williams.

General Crude-Oil-Supply Subcommittee

Parker Kendall, S. M. Nixon, J. H. Russell, and J. R. Suman.

General Products Supply Subcommittee

A. L. Christy, H. W. Ferguson, and J. M. Thompson.

General Statistical Subcommittee

G. L. Bonar, T. R. Goebel, R. J. Gonzales, D. G. Gray, Joe Hyer, Parker Kendall, J. E. Kelly, and H. S. Lane.

Supplies and Distribution Subcommittee

C. H. Alexander, B. H. Barnes, C. B. Barrett, G. W. Bowes, J. H. Boyle, T. M. Gordon, D. P. Hamilton, Winston Henry, R. W. Pack, A. F. Reed, G. L. Rowsey, G. N. Shanor, and Raymond Tollett.

Manpower Subcommittee

H. H. Anderson, B. Aston, F. T. Baldwin, R. M. Berry, F. Brown, G. Byers, H. Canon, J. P. Chambers, A. E. Chester, M. V. Cousins, K. R. Dailey, H. Decker, K. W. Dorman, J. E. Dunn, C. Fitzgerald, J. Foster, T. P. Fulton, T. R. Goebel, L. B. Gough, J. F. Hansard, T. H. Harder, L. Hays, H. P. Holmes, R. H. Horton, J. H. Kelly, K. B. Knox, R. B. McLaughlin, W. F. Matheny, B. Mills, M. J. Morrell, W. C. Morris, W. H. Moser, R. Mulvey, K. S. Myers, D. A. Powell, D. W. Rhea, T. J. Riley, A. H. Rowan, C. L. St. Clair, F. Sehman, C. Smith, J. Thomas, H. S. Warner, L. J. Whetsell, C. R. Williams, and R. Wolff.

Materials Subcommittee

R. H. Armstrong, B. H. Barnes, H. M. Brown, L. S. Cooper, O. Cummings, L. G. Dufilho, A. C. Fischofer, A. F. Fritchie, E. W. Cross, F. G. Hawk, S. Harper, F. L. Hereford, W. L. James, E. P. Krumholz, G. L. Parsons, N. Prichard, C. W. Redman, G. L. Redman, J. B. Rogerson, A. L. Sawyer, S. B. Schapiro, J. C. Senter, J. L. Sewell, O. D. Story, J. A. Tennant, J. J. Thomas, J. Vinson, F. A. Watts, and C. Young.

Exploration Subcommittee

M. V. Cousins, K. R. Dailey, J. A. Gillin, M. T. Higgs, S. A. Judson, F. H. Lahee, L. K. Lee, P. F. Martyn, L. W. Orynski, F. F. Reynolds, L. A. Scholl, Jr., and Paul Weaver.

Reserves and Development Subcommittee

D. V. Carter, E. DeGolyer, Alexander Deussen, H. F. Fuqua, E. P. Hayes, J. S. Ivy, B. G. Martin, Perry Olcott, A. L. Selig, and Robert Tesch.

Secondary-Recovery Subcommittee

O. C. Bailey, E. O. Buck, P. P. Gregory, E. H. Griswold, C. P. McGaha, and Glenn Staley.

Refining Capacity Subcommittee

R. T. Colquette, F. P. Dodge, W. G. Hiatt, E. N. Lewis, Charles Morgan, S. S. Seltzer, O. B. Stephens, Herman Taylor, R. L. Vernor, and L. E. Vivien.

Refining Plant Protection Subcommittee

A. B. Moore, Sam Seltzer, Jr., P. J. Sweeny, and F. L. Wallace.

Refining Statistical Subcommittee

C. A. Barrere, J. A. Bartlett, Sylvester Dayson, W. G. Horstman, H. E. Kelley, Parker Kendall, W. L. McKinnon, J. B. Mull, G. W. Poorman, K. W. Shimeall, W. F. Sims, and P. J. Sweeny.

Product Supplies for War Emergency Pipe Line Subcommittee

J. S. Allen, B. H. Barnes, P. E. Hurley, Joe Hyer, Parker Kendall, and J. W. Newton.

Refining Finance Subcommittee

F. P. Dodge, D. P. Hamilton, P. E. Hurley, J. M. Thompson, and R. H. Waser.

Crude Schedules Subcommittee

H. H. Baker, K. W. Bartlett, Parker Kendall, and J. W. Newton.

Aviation-Gasoline Refining Subcommittee

J. J. Allison, M. E. Baish, H. H. Baker, B. H. Barnes, O. L. Cordell, Sylvester Dayson, F. P. Dodge, M. E. Foster, D. P. Hamilton, Frank Holsten, D. W. Hovey, Parker Kendall, J. P. Langfitt, Ralph McIntyre, J. L. Miller, J. W. Newton, H. G. Osborn, R. B. Pierce, M. J. Rathbone, P. L. Robison, G. L. Rowsey, K. W. Shimeall, P. J. Sweeny, and Raymond Tollett.

Refining Specifications Subcommittee

R. C. Alden, L. S. Cannon, R. T. Colquette, A. B. Comstock, M. E. Foster, J. C. Hinds, W. W. Leach, R. B. Pierce, M. J. Rathbone, C. E. Robertson, and C. F. Watson.

Refining Technical Subcommittees

J. C. Allen, R. G. Anderson, R. O. Anderson, K. D. Andres, J. L. Anning.

B. F. Babin, N. S. Bants, J. A. Bartlett, O. S. Bearden, J. W. Bertetti, R. N. Blaize, W. S. Bonnell, C. C. Book, H. Bottomley, E. J. Bray, J. M. Brown, J. E. Burgess, J. A. Burns, T. J. Byrne.

C. W. Cannon, W. P. Cecil, V. B. Chance, J. N. Chatfield, W. H. Clark, R. C. Cole, G. A. Collins, Jr., R. M. Cooper, C. M. Cox, W. T. Cravens, L. C. Crockett, R. L. Crouchet.

F. E. Darling, R. F. Davies, R. Davy, R. E. Deeds, J. W. Deleplaine, R. N. Doremus, B. R. Dorsey, L. B. Dorsey, H. G. Drickamer, J. B. Dunlap, N. C. Dunn.

J. G. Eckhouse, C. Edwards, E. F. English, H. O. Evinger, D. H. Ezzell.

C. S. Faulkner, R. E. Feasel, J. E. Fenex, H. W. Ferguson, H. J. Fernandez, J. S. Finger, H. E. Fischer, E. J. Fisher, B. Fogleman, F. C. Fowler, J. M. Fox, W. B. Franklin, W. M. Frech, H. R. Freund, M. A. Furth.

T. E. Garrard, A. H. Garrison, O. Gerbes, B. V. D. Gerhart, S. F. Good, J. B. Goodwin, H. A. Grebe, W. W. Gremmel, R. R. Gumaer.

W. A. Hall, T. C. Hallmark, J. B. Hamblen, J. D. Haney, W. D. Harbert, J. Harris, R. C. Hartman, A. M. Hegwer, W. W. Hitchcock, D. K. Hoff, M. C. Hopkins, L. A. Horning, W. B. Howard, Jr., B. C. Hunter, D. E. Huth, J. Hyer.

G. A. Ibach, R. I. Jacobi, W. S. Jannsen, F. Jenkins, B. Johnson, E. C. Johnson, D. T. Jones, J. L. Jordan.

P. A. Kahle, Jr., W. W. Keeler, W. P. Kelly, R. B. Kennedy, E. Klaeger, C. H. Kollenberg, F. M. Kopf, M. J. Kovalik, D. J. Kraeger, C. W. Kraemer, B. A. Kreiter, F. Kunreuther.

M. O. Leach, P. L. Lee, A. B. Leonard, E. J. LeRoi, A. Lucadano, O. F. Luer, F. Lutteman.

C. R. McCullough, J. H. McCullough, G. E. McKenna, H. W. McRobbie, E. C. Magee, V. A. Maggio, P. A. Maschwitz, T. R. Mason, A. G. Meakin, R. J. Metcalf, D. N. Mills, B. E. Milner, C. E. Mitchell, J. W. Mitchell, L. G. Molique, G. W. Moyer, J. B. Moyers, O. O. Myers, R. S. Myers.

J. R. Neely, N. Newton, W. L. Owen, F. M. Orr, J. S. Palmer, N. P. Peet, C. O. Payton, G. W. Poorman, B. H. Price, J. B. Price.

R. Y. Rankin, J. J. Rasor, K. A. Rees, C. A. Renfer, L. A. Reuter, C. Richker, G. F. de Ridder, G. L. Riegner, O. C. Roberson, W. C. Rooks, R. S. Ross, C. Rylander, Jr.

J. A. Scott, J. F. Scott, K. W. Shimeall, J. E. Shoemaker, F. J. Smith, L. L. Smith, P. L. Smith, H. R. Snow, W. R. Sorenson, J. L. Sperry, G. E. Springer, R. F. Stahl, C. P. Stanley, A. J. Stewart, J. E. Storment, K. O. Stowell, L. R. Strawn, W. A. Sullender, T. E. Sullivan, A. J. Surowiec, W. P. Svec, D. O. Swan.

J. W. Talbert, G. Tate, W. M. Terry, R. B. Thompson, R. C. Thorgeson, K. E. Thorp, R. F. Trow, J. Urie.

C. F. Van Berg, H. M. Vaughn, L. H. Vautrain, R. H. Venn, W. P. Voiles, H. Voorhies.

P. M. Waddill, H. R. Wall, R. C. Ward, R. R. L. Ward, J. H. Weiland, C. E. Wendt, F. M. Wiggins, H. D. Wilde, H. B. Willard, L. M. Williams, R. M. Willis, R. C. Wilson, W. M. Wilson, A. Wizig, D. W. Wright, E. P. Zehner, and C. Zimmerman.

Synthetic-Rubber Subcommittee

R. T. Atkinson, T. S. Bacon, W. F. Fulton, M. H. Kotzebue, C. E. Wharton, and C. R. Williams.

Natural-Gasoline Product Movements Subcommittee

Clyde Alexander, F. M. Blair, J. H. Boyle, A. F. Garrett, M. L. Mayfield, and L. J. Wilmeth.

Natural-Gas and Condensate Reserve Subcommittee

R. C. Becker, F. M. Blair, Alan Bruyere, R. O. Garrett, L. B. Herring, M. L. Mayfield, Perry Olcott, L. T. Potter, C. R. Turner, and H. C. Webb.

Isobutane Subcommittee

G. L. Brennan, J. W. Martin, and G. T. Tennison.

Liquefied-Petroleum-Gas Subcommittee

Louis Abramson, Jr., W. A. Baden, G. L. Brennan, B. T. Harris, J. W. Martin, M. L. Mayfield, and T. A. Sacra.

Natural-Gasoline Aviation-Gasoline Potentialities Subcommittee

J. H. Dunn, W. F. Fulton, R. D. Hanley, J. T. Jordon, and C. R. Williams.

Pipe-Line Subcommittee

Charles Fitzgerald, J. L. Latimer, R. B. McLaughlin, G. L. Rowsey, and T. E. Swigart.

Coastwise and Inland Waterways Subcommittee

A. W. Frey, C. L. Hand, J. W. Hershey, Maston Nixon, W. W. Tennant, and S. C. Trimble.

Tank-Car and Tank-Truck Subcommittee

P. G. Anderson, Jack Fleming, J. P. Gudger, W. M. Maddox, Douglas Orme, and Sam Short.

Transportation Joint Use of Facilities Subcommittee

M. T. Ball, G. O. Irvine, E. C. Kincade, J. S. Leach, W. M. Maddox, Maston Nixon, G. L. Rowsey, T. E. Swigart, and W. W. Tennant.

Marketing Containers Subcommittee

J. B. Anthony, J. P. Connell, R. B. Dodson, H. S. Gwyn, S. S. Morris, J. E. Niland, C. R. Olson,, and W. H. Saunders.

Marketing Equipment Subcommittee

J. C. Anthony, R. B. Dodson, A. C. Fischofer, R. B. Frances, George Radford, Wallace Rew, R. E. Risser.

Advertising Subcommittee

C. A. Barnes, G. D. Bowers, L. P. Carter, S. H. Dunken, Albert Evans, Jr., G. C. Gibbons, Arthur Lefevre, Jr., W. R. Lund, Lester Moore, C. R. Olson, S. W. Papert, A. B. Penny, P. W. Riggins, G. W. Reed, Don Riddle, Kenneth Rothermel, P. J. Ward, H. L. Way, and George Wilson.

Asphalt Subcommittee

Harold Buck, John Coit, Inghram Grayson, L. W. Kemp, Frank Odom, H. B. Pullar, W. H. Rhodes, W. L. Scott, B. A. Storm, and Roger Williams.

XUM

District 4 Advisory Committees

General Committee

H. E. Clack, W. H. Ferguson, R. W. Hendee, J. A. Lentz, H. D. Moyle, B. W. Musser, R. S. Shannon.

Production Committee

F. C. Brunner, A. B. Cobb, J. F. Cullen, R. B. Curran, H. D. Curtis, S. W. Hardison, W. M. Holland, A. E. Johnson, V. M. Kirk, G. N. McCabe, J. R. McWilliams, J. P. Moroney, J. C. Peters, G. F. Poe, R. S. Shannon, H. A. Stewart, P. Stock, E. J. Sullivan, C. P. Watson, C. N. Wrighter.

Refining Committee

E. L. Allen, F. W. Bird, C. C. Buchler, W. G. Copeland, K. H. Davis, P. N. Fortin, C. O. Garbrecht, D. O. Gray, D. E. Hageman, E. S. Holt, T. J. Landry, H. S. McCray, E. A. Markey, C. Morgan, H. D. Moyle, M. H. Nolan, E. M. Parkin, F. L. Perry, E. T. Pummill, M. H. Robineau, L. L. Smith, P. A. Thomson.

Natural Gas and Gasoline Committee

J. T. Bishop, D. B. Coolidge, R. W. Hendee, J. C. Johnston, R. W. Leslie, J. M. McIntire, F. T. Parks, J. D. Roberts, C. W. Smith, R. C. Smith.

Supply and Transportation Committee

J. A. Bruso, C. W. Butler, G. M. Dolezal, R. B. Hamilton, L. R. Hawley, H. H. Healy, P. M. Hirth, G. Moyle, B. M. Musser, G. E. Nielsen, L. B. O'Neill, K. D. Pardee, C. R. Parish, R. V. Rodman, E. H. Rust, F. Van Iderstine, C. J. Westcott.

Distribution and Marketing Committee

H. E. Armitage, D. F. Benton, H. E. Clack, W. E. Dineen, C. H. Dodson, F. C. Fogarty, M. J. Greenwood, E. R. Kindler, J. A. Lentz, J. H. Mabee, F. J. Maine, H. W. Orchard, C. W. Overton, J. H. Payne, H. T. Rapp, G. W. Schwert, W. E. Thomas, K. W. Yeates.

Materials Subcommittee

C. C. Buchler, A. B. Cobb, J. F. Cullen, D. O. Gray, H. H. Healy, L. Iiams, J. O. Johnston, F. E. Merrill, C. Morgan, J. H. Payne, L. Weiss, I. Wetherill.

Geological Subcommittee

J. D. Anderson, J. H. Barnett, A. F. Barrett, A. E. Brainerd, R. D. Copley, E. B. Emrick, H. B. Gernert, T. S. Harrison, J. E. Hupp, R. P. Jackson, D. E. Jones, E. W. Krampert, P. La Fleiche, G. N. McCabe, C. F. Nichols, W. T. Nightingale, F. C. Platt, G. F. Poe, R. Poynter, L. S. Robinson, R. L. Sulaff, W. D. Shelton, N. A. Slagter, C. N. Wrighter.

Secondary-Recovery Subcommittee

J. D. Anderson, J. H. Barnett, D. E. Jones, R. A. McAvoy, N. A. Slagter, M. L. Terry.

Refining Technical Subcommittee

C. C. Buchler, W. G. Copeland, T. H. Corbett, C. A. Cromwell, R. W. Leslie, C. Morgan, A. W. Neeley, M. H. Nolan, E. M. Parkin, P. A. Thomson.

Liquefied Petroleum Gas Subcommittee

T. H. Anderson, S. J. Connolly, M. P. Huntington, C. R. Husted, R. W. Leslie, H. R. Torbit.

Asphalt Subcommittee

C. E. Cox, D. R. Donlin, T. R. Ellis, M. J. Greenwood, C. Myhre, C. Nix, G. E. Nielson, R. A. Short, J. D. Wilkie.

Joint Use of Facilities Subcommittee

H. E. Armitage, D. F. Benton, J. T. Bishop, J. A. Bruso, C. C. Buckler, H. E. Clack, A. B. Cobb, S. J. Connolly, D. B. Coolidge, W. G. Copeland, J. F. Cullen, C. O. Garbrecht, M. J. Greenwood, H. H. Healy, R. W. Hendee, P. M. Hirth, E. S. Holt, A. E. Johnson, J. C. Johnston, E. R. Kindler, T. J. Landry, J. A. Lentz, G. N. McCabe, J. M. McIntire, F. J. Maine, C. Morgan, G. Moyle, H. D. Moyle, B. W. Musser, G. E. Nielson, H. W. Orchard, C. R. Parish, E. M. Parkin, F. T. Parks, G. F. Poe, H. T. Rapp, J. D. Roberts, M. H. Robineau, R. V. Rodman, R. S. Shannon, C. J. Shortess, C. W. Smith, R. D. Smith, H. A. Stewart, W. A. Strimple, P. A. Thomson, C. P. Watson, K. W. Yeates.

District 5 Advisory Committees

General Committee

C. S. Beesemyer, W. F. Humphreys, C. S. Jones, W. Moeller, E. E. Pyles, W. L. Stewart, Jr.

Production Committee

L. L. Aubert, F. S. Bryant, R. E. Collom, L. A. Cranson, E. D. Cumming, E. F. Davis, L. C. Decius, E. B. Hall, W. M. Keck, Jr., Ross McCollum, A. D. Mitchell, B. E. Parsons, E. E. Pyles, L. P. St. Clair, H. T. Sutherland, J. B. Sutherland, W. C. Whaley, Lloyd Williamson, F. M. Ziegler.

Refining Committee

L. F. Bayer, C. S. Cox, F. S. Clulow, D. E. Day, S. J. Dickey, O. C. Field, R. G. Follis, J. L. Hanna, C. A. Johnson, A. M. Kelly, E. V. McKinzie, Maurice Machris, Bernard O'Connor, H. S. Rothschild, W. L. Stewart, Ray Wheeler, C. S. Wimpress.

Natural-Gas and Natural-Gasoline

A. F. Bridge, L. V. Cassaday, H. L. Eggleston, H. L. Farrar, R. H. Green, R. W. Heath, H. R. Linhoff, E. H. McCollough, P. S. Magruder, William Moeller, Jr., G. F. Schroeder, G. L. Tyler, W. G. Vincent.

Supply and Transportation

C. S. Cox, E. T. Earl, J. L. Hanna, H. S. Holloway, C. S. Jones, R. L. Minckler, H. R. Pauley, A. C. Saul, N. F. Simmonds, J. A. Tench, C. P. Watson, T. H. Webb.

Marketing Committee

P. E. Allan, D. E. Beaton, C. S. Beesemyer, A. H. De Friest, B. E. Devere, C. A. Johnson, Dewitt Knox, L. G. McLaren, O. W. March, A. G. Mayfield, Walter Nielsen, T. S. Peterson, A. C. Stewart, Cecil True.

Members of Subcommittees of District 5 Advisory Committees

C. M. Ambrose, W. S. Ackerman, G. Adams, M. S. App, H. W. Abruns, R. M. Allen, Jr., J. H. Abramson, E. L. Adams, E. L. Archibald.

H. A. Baugh, G. Brereton, A. F. Bridge, R. M. Bauer, P. E. Beckman, A. H. Bell, R. C. Barton, T. W. Bell, L. F. Bayer, F. Behrens, H. E. Boner, W. E. Bradley, C. H. Britten, C. Beal, H. A. Brett, E. L. Black, L. Bowen, E. R. Burns, W. Brayton, E. J. Bartosh, J. C. Beck, F. P. Brandt.

T. B. Crowley, Jr., F. E. Coyle, R. F. Childs, L. V. Cassaday, L. A. Cranson, A. H. Calderwood, W. Craddock, E. P. Crail, J. W. Chartrand, T. D. Cook, D. E. Carr, G. H. Cherry, Jr., R. D. Colvin, W. Clark, E. E. Combs, W. H. Cree, A. D. Carleton, C. L. Crary, W. A. Clark, D. L. Caldwell, H. Campbell, A. J. Crites, W. C. Camp, D. A. Cushman.

W. C. Dayhuff, G. A. Davidson, M. Dice, W. T. Dinkins, R. M. Dewar, Q. S. Diven, R. C. Davis, W. W. Davison, T. R. Dwyer, C. F. Dolley, D. D. Dunlap, C. Duke C. E. Donaldson, D. E. Dobler.

H. L. Eggleston, C. E. Emmons, J. M. Evans, R. Earle, D. W. Elliott, W. Everts.

P. E. Foote, O. C. Field, M. L. Fort, M. E. Ford, R. H. Fleser, H. L. Farrar, E. H. Fisher, W. S. Fisher, C. F. Fenema.

C. D. Gard, G. C. Gester, A. H. B. Gore, R. H. Green, J. H. Grimes, R. H. Garrison, H. Gilstrap.

J. B. Hill, G. N. Hile, B. Hopper, R. A. Halloran, T. F. Harms, H. G. Henderson, H. B. Haney, W. T. Hancock, C. K. Hewes, W. P. Hugo, H. Y. Hyde, R. Harsh, J. E. Hathaway, W. W. Hay, R. Hutcherson, J. Hancock, W. L. Hobro, R. A. Holman, R. P. Huggins, D. Hogan, J. Herley, C. L. Holm, C. F. Hertle.

F. Isaacs, W. H. Ireland, S. A. Ironside.

W. T. Joplin, D. B. Johns, J. Jensen, A. S. Johnston, L. D. Jurs.

M. W. Kibre, F. H. Krebs, W. H. Kraft, J. Keene, G. M. Kilmer, K. E. Kingman, M. T. Kendall, B. P. Kantzer, D. G. Kingman, L. C. Kelly, E. Kluth.

H. R. Linhoff, W. C. Lynch, O. Liddell, J. F. Lynch, R. S. Lytle, H. H. Lewin, A. W. Lyddon, P. C. Lamb.

P. H. Moore, N. H. Mull, P. S. Magruder, S. F. Magor, R. McCollum, Clyde Marsh, A. C. Maynard, C. E. McCartney, C. C. Moore, J. H. MacGaregill, B. A. Moeller, W. T. Moore, E. H. McCollough, F. R. Marshall, A. G. Marshall, L. A. Marston, J. M. McElwain, E. H. McNamara, L. Mittelman, O. H. Muller, J. G. McLeod, C. E. McCartney, H. H. Magee, A. B. McCloskey, S. McIntyre, C. H. Morton, M. V. Moulton, F. Maurer, W. J. McGillivray, L. C. Monroe, E. V. Macon, W. H. Murphey, J. S. Norris, W. O. Narry.

G. F. Olson, D. B. O'Neill, J. J. Oliphant, H. F. Owen, F. O'Brien.

L. E. Porter, D. D. Purrington, H. Pyles, H. M. Paulsen, G. L. Powell, H. Power, R. M. Pyles, W. H. Philleo, T. W. Peters, G. T. Pearson, H. Pauley, C. A. Phelan, J. L. Potter, R. C. Patterson, C. Pearson, J. H. Puls, J. W. Paulsen, C. Prewett, A. F. Petterson.

T. Ransome, G. V. S. Randall, F. F. Rumbley, A. C. Rubel, C. F. Ramey, B. H. Robinson, T. H. Rodgers, D. P. Riley, L. R. Rogers, O. R. Roskway, G. Ring, C. M. Rood, E. W. Randolph, B. Ribi[illegible]n, J. D. Rearden.

C. A. Swigart, O. M. Slosson, N. Simmons, D. Smith, J. W. Staples, G. F. Schroeder, H. J. Steitz, J. I. Sheridan, J. Salmond, H. S. Stark, J. L. Stephens, J. B. Stevens, J. B. Sutherland, D. H. Sheldon, F. B. Simms, T. H. Sherman, J. H. Sargent, R. J. Stevens, C. W. Stephens, E. L. Smith, C. C. Spicer, A. E. Sykes.

T. Taggart, R. S. Tulin, D. T. Tadich, M. E. Tracy, G. L. Tyler, J. A. Tench, O. P. Tucker, O. I. Torkelsen, J. P. Terry, R. B. Truman, J. B. Taylor, A. F. Turman.

W. G. Vincent, T. Vreeland, R. Von Hagen.

R. Winterburn, E. W. Wagy, M. Weil, A. F. White, D. K. Weaver, A. O. Woll, V. R. G. Wilbur, H. O. Woodruff, T. R. Williams, W. R. Wardner.

E. J. Young. C. F. Yunker.

Pressure Maintenance by Water Injection, Midway Field, Arkansas

by William L. Horner *

A.P.I.

ABSTRACT

Conclusive results are now available from operation of the first project for maintenance of pressure over an entire pool by injection of extraneous water. Data obtained from 28 months of operation indicate the following results: (1) the possibility that the amount of oil recoverable during the primary stage is doubled; (2) the permissible rate of production is indicated to be twice the rate expected if injection had not been successful; (3) the costs are reasonable.

The field produces from the Smackover limestone formation at a depth of about 6,500 ft. Four dry holes, converted to injection wells, receive currently approximately 8,000 bbl. per day of fresh water plus 1,000 bbl. per day of salt water disposed from lease-tank batteries. All of the water is injected by applying approximately 50 hp.

On September 1, 1945, the pool had produced 7,500,000 bbl. of oil, and 5,000,000 bbl. of water had been injected. Prior to the injection project which commenced in April 1943, reservoir pressures had fallen 20 psi. per month, with an oil-production rate of 5,500 bbl. daily. Since February 1, 1944, reservoir pressures have risen 65 psi., with current oil-production rates up to 7,500 bbl. per day.

For other oil and gas pools it is suggested that, if this procedure is selected, following careful study of the pool performance, diligent engineering control should be exercised in order to insure maximum success in applying the process described.

Introduction

CONSIDERABLE interest is manifested toward pool-wide application of pressure maintenance by water injection as a means of adding to the recovery from oil and gas fields. Data obtained at Midway disclose conclusive results, and confirm indications which were outlined before a meeting of the Division of Production of the Institute at Chicago, November 11, 1943.[1] Since that date pressure, production, and cost records have been accumulated—which may be deemed of timely importance. The earlier publication referred to showed that injection into one well, located at the edge of a pool, 1,800 acres in area caused a marked decrease in the rate of pressure decline in the pool. Since then injection has been maintained in four wells, with the result that reservoir pressures have risen — although during the same period allowables and withdrawal rates have been increased substantially.

Pool Conditions

The pool contains 41 producing wells which were completed between January 1942 and December 1943. Eight wells, initially of low productivity, are equipped for artificial lift. A productive area of approximately 1,800 acres is shown to be located on an anticlinal structure (Fig. 1), and has been found by several independent methods to contain approximately 150,000,000 to 160,000,000 bbl. of stock-tank oil in place. There is no gas cap, the oil being uniformly saturated with gas at a pressure of 2,528 psig., a pressure which may be compared with the pool average of 2,674 psi. on July 1 and 2,920 psi. at discovery.

The original limits of the pool appear to be defined roughly by contact of the top of the porosity with the datum of 6,225 ft. below sea level. In several instances the water-

*Barnsdall Oil Co., Tulsa, Okla.

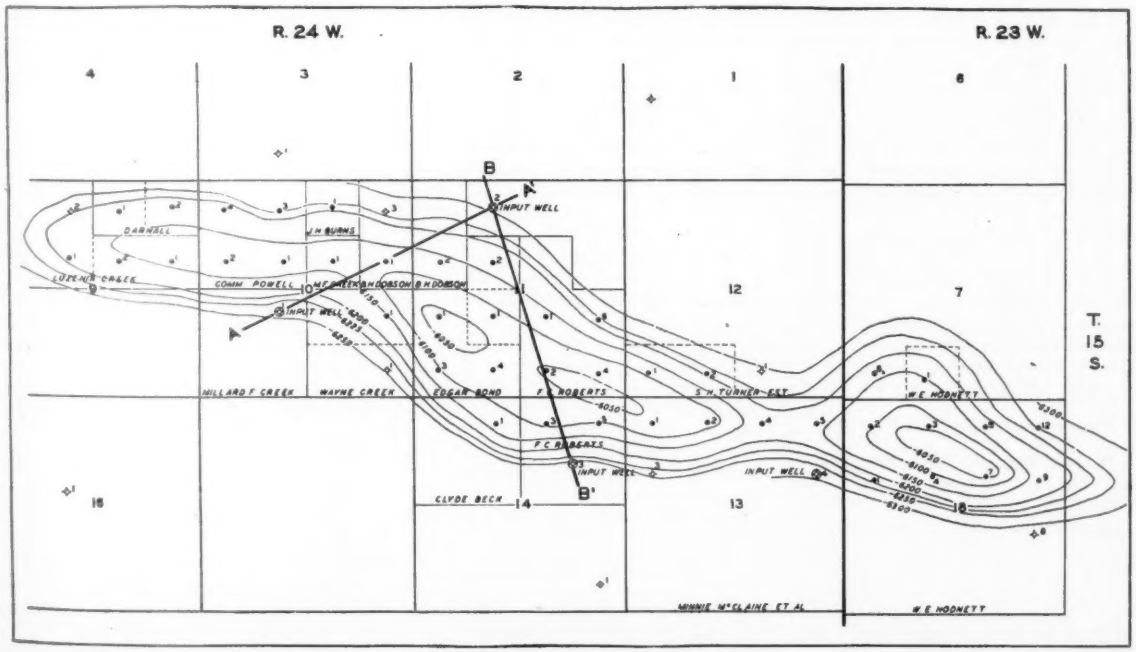


Fig. 1—Contours of Midway field, Arkansas

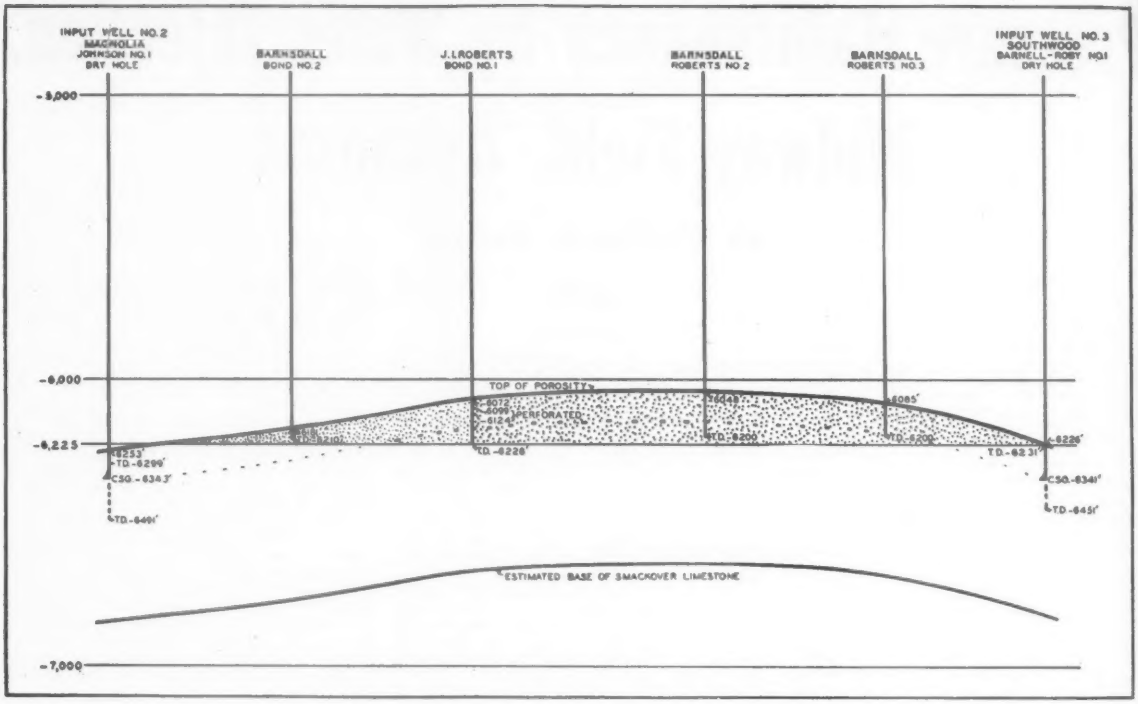


Fig. 2—Cross-section of Midway field, Arkansas

oil contact appears to have been higher, and in some cases lower. The estimate of about 160,000,000 bbl. of stock-tank oil originally in place has been made on a basis of porosity and acre-feet of formation. This value is in close agreement with the value determined by W. A. Bruce in a summary published of the results of his analysis of the pool-performance history.[2] The position of the oil with respect to the water underlying the pool is shown diagrammatically by a cross-section drawn north and south across the center of the pool (Fig. 2). Logs of wells drilled through the oil column indicate that the formation is generally permeable and water-bearing at all points below the oil-water contact throughout the pool. External energy for maintenance of pressure in the pool is believed to be transmitted to the pool primarily through the underlying water. Pool-wide contact of the water table with the oil contained in the reservoir appears to facilitate communication of pressure throughout the pool.

Pressure-Production History

On January 14, 1942, the initial reservoir pressure for the pool was determined to be 2,920 psi. at 6,050 ft. below sea level, and by May 25, 1943, had fallen 261 psi. to a value of 2,659 psi. The reservoir oil has a bubble-point pressure of 2,528 psig., and a compressibility of 15.0 bbl. per million barrels per pound per square inch pressure at reservoir conditions.

Factual data published by the Arkansas Oil and Gas Commission[3] state that, for the 3-month period ending May 25, 1943: "The greatest decrease in pressure among the water-driven oil fields was experienced at Midway with a drop in pressure of 0.56 psi. daily." During that 3-month period average production of oil was approximately 5,600 bbl. per day. Injection was commenced April 19, 1943, and the record shows influence of injection on the pressure-production history (Fig. 3). Data published by the commission (July 1945) show that, for the first 6 months of 1945, reservoir pressures increased 0.09 psi. per day, whereas oil production had been raised to an average of more than 6,900 bbl. per day. Constant allowables were granted for an extended period. This fact aided greatly in interpreting results of injection. On February 1 the daily base allowable per well was increased from 175 to 200 bbl. per day. The average oil-production rate during August 1945 exceeded 7,500 bbl. per day.

In addition to the oil recovered, liquids extracted by the gasoline plant averaged 23,700 gal. daily during the same month. Design and operation of the plant are facilitated by the richness of the gas, steady allowables, and constant gas-oil ratio.

Distribution of Pressure

With few exceptions since injection began, reservoir pressures have been measured monthly on one-third of the wells in the pool. The pressures of no individual wells appear abnormally high as a result of injection (Table 1). An examination of all the pressure data since injection started discloses that a transient effect is noticeable on producing wells around injection wells. During the first 30 to 60 days after injection commences or has been increased markedly, reservoir pressures measured in the offset wells increase at rates above the pool average, and thereafter the pressures observed return to a position in line with the remainder of the wells. Wells offsetting injection wells likewise are noticed to be only average producers of water. In August 1945 oil wells nearest input wells No. 1, 2, 3, and 4 produced (respectively) the following percentages of water: 0.3, 6.0, 2.8, and 2.0. During the same period it

TABLE 1—RESERVOIR-PRESSURE DISTRIBUTION—MIDWAY FIELD, ARKANSAS

Pressure (psi.) at 6,050 ft. below sea level	April 1,	June 1,
Well—	1944*	1945†
Edgar Bond 1	2,621	2,687
Edgar Bond 3	2,619	2,693
M. F. Creek 1	2,629	2,673
Charles McClaine 1	2,608	2,687
Charles McClaine 2	2,595	2,667
Charles McClaine 5	2,653	2,684
Community Powell 1	2,634	2,645
Community Powell 2	2,598	2,605
F. C. Roberts 3	2,617	2,684
Roberts' Edgar Bond 1	2,621	2,680
W. E. Hodnett 3	2,655	2,670
W. E. Hodnett 7	2,680	2,686

*Arkansas Oil and Gas Commission Factual Data No. 36, April 26, 1944. †Arkansas Oil and Gas Commission Factual Data No. 41, July 26, 1945.

is estimated the pool production averaged 12 per cent water.

Probable Pressure-Production History Without Injection

The oil-production rate during August 1945 averaged over 7,500 bbl. daily. Total reservoir withdrawals, including shrinkage and 1,000 bbl. of salt water, totaled 10,000 bbl. per day. Injection of at least 8,000 bbl. per day appears to be required to maintain pressures at present levels. Therefore, the rate of natural water drive has diminished to approximately 2,000 bbl. per day. On that assumption it can be computed that pressures could be maintained by restricting the rate of oil production to around 1,500 bbl. per day. However, it is believed that, in the absence of injection, a moderate degree of pressure decline would be tolerated by the state regulatory body, and a pool allowable of 3,500 to 4,000 bbl. per day could be expected.

Economics

The total operating expenses for the combined pressure-maintenance and salt-water project have declined rather steadily for the past 20 months, and averaged $70 per day for the 3 months ending September 1, 1945. Thus it may be inferred that the additional rate of recovery is obtained economically.

Evidence of the limited amount of natural water drive tends to confirm previous estimates[1] that, through injection, an additional 35,000,000 bbl. of oil could be produced to economic limit. The anticipated increase in ultimate yield may be compared with the costs for installing pressure-maintenance and salt-water-disposal facilities. These total less than one-tenth of the aggregate cost of discovery and development of the pool.

A third advantage gained by maintaining pressures is realized in reduction of requirements for artificial lifting of oil from producing wells. In addition to the benefits obtained from having higher pressures available to aid flowing, experience at Midway has disclosed that productivity indices of individual "clean" oil wells do not decline with time nor with accumulated production, provided the flowing bottom-hole pressures remain near or above the bubble-point pressure of the reservoir oil.

However, steady decline has been plotted from data on productivity-index measurements for some other wells in the pool which are required to operate with bottom-hole pressures considerably less than the bubble-point pressure (Fig. 4). The behavior of productivity indices of these wells is interpreted as being in line with accepted principles and theories. The productive formation at Midway is a porous limestone largely soluble in hydrochloric acid. In order to maintain production rates, it has been possible to employ new acidizing techniques to raise to a maximum the productivity-index values for seven wells whose flowing life would have been shortened.

Injection Facilities

To expedite: an operating agreement for the project alone was drafted rather than unitization for the entire pool. Because only equities and responsibilities pertaining to the project were involved, the operators decided promptly. The agreement among the six operators in the field was made and entered into July 20, 1943. Approval was granted by the commission, which is empowered in such matters by a state law.[4] In the provisions of the agreement, the operator of the project "never shall be held to be liable for any results that may occur to the producing formation or any part thereof because of the operation of the system." Each party to the contract shares investment costs and expenses in proportion to the percentage of reserves computed to be recoverable from under each producing tract. However, to maintain pressure and dispose of salt water, production of oil from the individ-

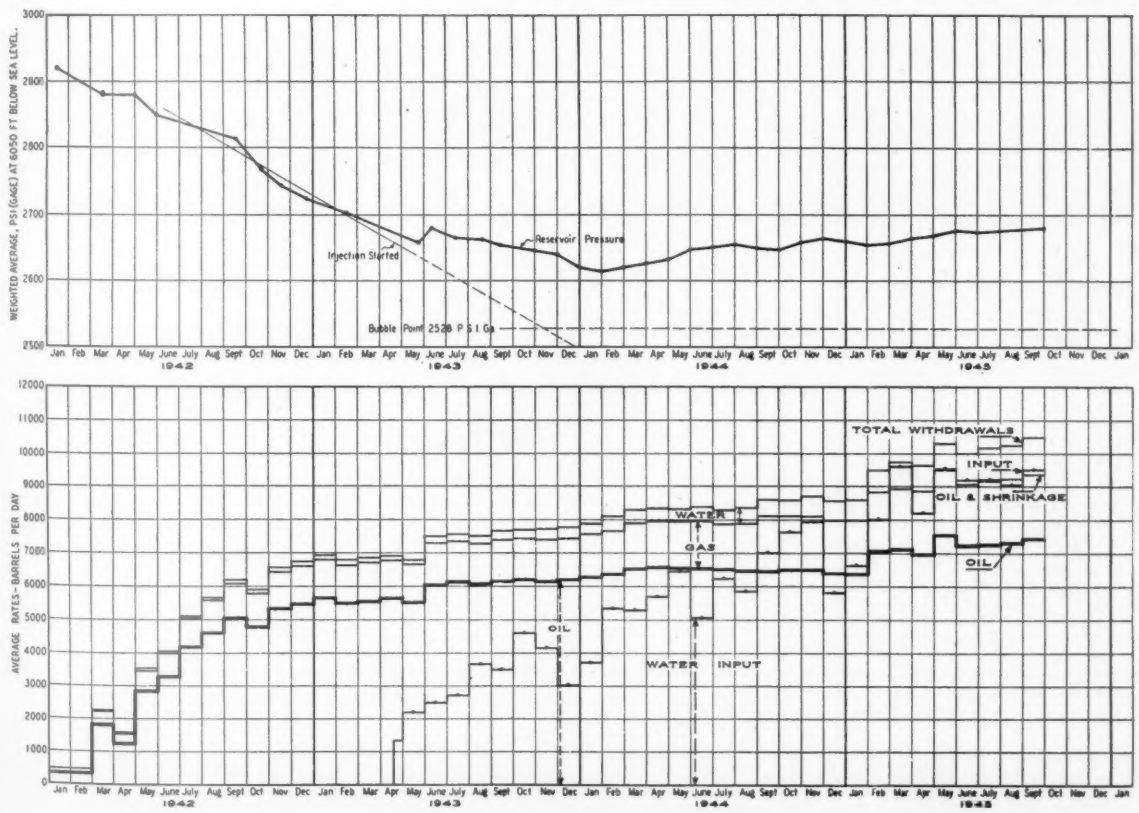


Fig. 3—Production data, Midway field, Arkansas

ual leases and wells is carried on independently of the joint agreement.

In addition to an agreement between the operators, permission was obtained from the several hundred owners of mineral and royalty interests in oil and gas leases covering lands producing, and also containing, injection wells.

The contract listed the following principal items:

1. Distribution lines (steel pipe, cement lined)	$ 19,585.00
2. Four input wells (converted from dry holes)	103,151.05
3. Water supply and pressure plant (centrally located plant)	23,960.00
4. Salt-water gathering lines (7.4 miles of cement-asbestos pipe line)	61.688.06

The facilities described in the contract were installed. Due to the small capacity of fresh-water wells, it has been necessary to operate six individual wells which have an average capacity of less than 2,000 bbl. per day each. The fresh - water - supply wells are situated within the field, and are spaced over a distance of approximately 3 miles. All of the water produced from these wells, as well as the salt water gathered from several tank batteries, is kept out of contact with air. At a central point in the field the fresh-water and salt-water gathering lines are led separately to two low-form 500-bbl. standard steel tanks.

Oil gathering on the surface of the water in the tanks is skimmed by overflow, and soils settling out during the 2-hour retention period are periodically removed. A blanket of gas at a pressure of 1 oz. is maintained on the surface so as to exclude atmospheric oxygen. Two pumps driven by gas engines distribute the water from this central point to the four injection wells. Although several of the wells would require less pressure for injection, the pumps are regulated to discharge at a pressure of approximately 450 psi. in order to simplify manifolding. It is interesting to observe that this procedure raises power requirements to a water horsepower of 68. In effect, only about 50 hp. is applied to the water injected after it leaves the central gathering tanks.

In general, a uniform procedure was followed for converting the four edge dry holes to injection wells. In each instance (Table 2) casing was set at a point at least 115 ft. below the assumed oil-water contact, and approximately 130 ft. of formation remained exposed below the casing shoe. After the drilling mud had been replaced with water, the hole was enlarged $\frac{1}{16}$ in. in radius with a rotary wall scraper, and backflow was induced. After a preliminary injection test, 15 per cent acid was introduced in amounts which ranged up to 16,000 gal. per well—immediately followed by injection of water. The first well was treated initially with 7,000 gal. It was later acidized with an additional 10,000 gal. to increase its injectivity. This permitted the well to take water at pressures and rates comparable to wells No. 2 and 4. By September 1, 1945, a total volume in excess of 5,000,000 bbl. of water had been injected, more than 1,000,000 bbl. to each of the input wells; and the intake capacities of the wells have remained practically at the original levels.

The fresh water is of potable quality. The brine produced with the oil contains approximately 26 per cent salts. Samples of each water, exposed to the air, develop turbidity within a few minutes. However, samples of the waters taken from the injection lines remain clear indefinitely if collected under gas.

Applying the Method to Other Pools

The use of water injection to raise and maintain pressures in oil and gas fields is notably beyond the experimental stage. Currently there are almost 20 pools in the Mid-Continent and Gulf Coast[6] areas where expenditures have commenced for plans and projects of this type. Sev-

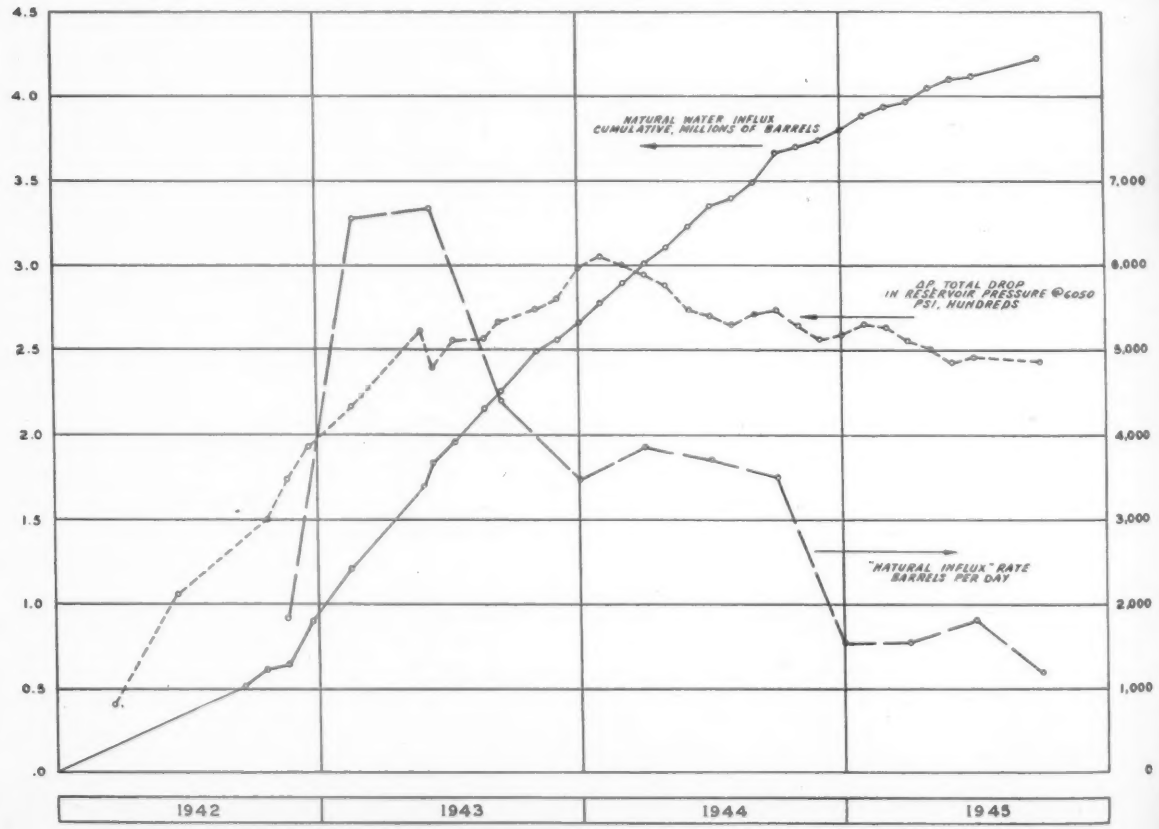
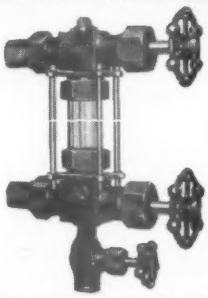


Fig. 4—Water-injection and pressure data, Midway field, Arkansas

PENBERTHY

"ALL IRON" WATER GAGE SET



Extra heavy construction throughout. Body made from special high strength alloy iron, shanks alloy steel and trim stainless steel. Automatic and positive shut-off if glass breaks, valves self-cleaning, dripless drain cock permits gradual blowing off of gage. Conforms with A.P.I.-A.S.M.E. requirements.

The Heavy Duty "All Iron" is one of the complete line of Penberthy gages that meets every liquid level gage requirement.

PENBERTHY INJECTOR CO.
DETROIT 2, MICH. Canadian Plant WINDSOR, ONTARIO

PENBERTHY

"REFLEX" WATER GAGE SET

For oil field, locomotive type and marine boilers. Water shows black — steam shows white; the water level is unmistakable. U-Bolt construction is strongest and simplest to service. Glass replaced by simply removing nuts on face of gage . . . unnecessary to work between gage and boiler. Conforms with A.S.M.E., Federal and State requirements when used for pressures specified by their respective codes.

This is one of the complete line of Penberthy gages that meet every liquid level gage requirement.

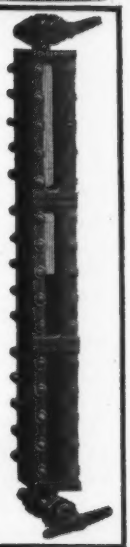
PENBERTHY INJECTOR CO.
DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

PENBERTHY

"REFLEX" DROP FORGED STEEL LIQUID LEVEL GAGES

Liquid always shows black—empty space shows white. Preferred where the liquid level must be easily and positively visible, and when liquids are under high pressure or at high temperature. Made of alloy temperature resisting steel and are highest quality throughout. Liquid chamber made from solid block of steel to assure perfect alignment and rigidity. Conform with A.P.I.—A.S.M.E. requirements.

The "Reflex" is one of the complete line of Penberthy Gages that meet every liquid level gage requirement.



PENBERTHY INJECTOR CO.
DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

PENBERTHY

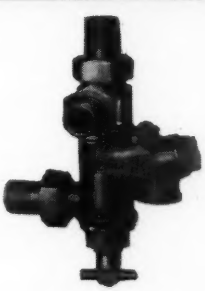
EJECTORS

Use the power of steam, air or water under pressure to lift liquids. Being simple jet pumps they have no moving parts and require no lubrication. A variety of models to meet different conditions. Also used as water heaters.

PENBERTHY INJECTOR CO.
DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

PENBERTHY

AUTOMATIC INJECTORS



The accepted method for assuring an uninterrupted supply of feed water to oil field boilers. Penberthy Automatic Injectors will supply feed water to boilers at minimum cost, are quickly and easily installed, reliable under most severe operating conditions, require little attention and no careful handling. Highest quality design and rugged construction.

PENBERTHY INJECTOR CO.
DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

PENBERTHY

SUMP PUMPS

Used wherever seepage water accumulates, the Penberthy Automatic Electric Sump Pump and the Penberthy Automatic Drainer (water or steam operated) have demonstrated their superiority in this service. Simple and rugged design—copper and bronze construction throughout.

PENBERTHY INJECTOR CO.
DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

XUM

TABLE 2—INJECTION-WELL DATA—MIDWAY FIELD, ARKANSAS

Completion—	No. 1	No. 2	No. 3	No. 4	
Total depth (derrick floor), ft.	6,765	6,778	6,720	6,742	
Total depth (below sea level), ft.	6,490	6,491	6,451	6,477	
Casing sizes (in.) at depth below sea level, ft.	5½; 6,343	6; 6,343	6; 6,341	5½; 6,354	
Top of porosity (below sea level), ft.	6,236	6,250	6,225	6,264	
Interval from assumed level of 6,225 ft. below sea level to casing shoe, ft.	118	118	116	129	
Formation exposed below casing shoe, ft.	147	148	110	123	
Operation, initial—					
Date injection started	4/19/43	1/5/44	3/24/44	10/24/43	
Estimated reservoir pressure in nearest well	2,630	2,603	2,610	2,675	
Estimated reservoir pressure in input well	2,636	2,606	2,608	2,689	
Initial injectivity, bbl. of water per day per pound per square inch pressure	3.6*-6.2	7.2	Over 50	7.4	
Operation, current—					
Injectivity after injection of 1,000,000 (plus) bbl.	5.8	6.8	55.0	7.2	
					Total
Injection rate (August 1945), average barrels per day	2,345	2,195	2,240	2,253	9,033
Cumulative injection (September 1, 1945), bbl.	1,822,988	1,160,621	1,002,126	1,014,654	5,000,389

*Reacidized.

eral of the principles demonstrated at Midway are applicable to all types of pools. Some conditions which now appear simple at Midway are known to be difficult and complex in several of the other pools whose projects are getting under way.

a. Oil pools.—The maintenance of pressure in thin-sand oil pools covering large areas should be found controlled to an important extent by the resistance of flow of oil through the formation across the pool. In such pools the transmission of pressure is necessarily through the oil. In pools in which the resistance to flow is high, pressures on the flanks will have to be maintained considerably higher than the resultant pool pressure desired.

b. Gas and condensate pools.—Favorable conditions for uniform distribution of pressure are found in the case of a high-pressure permeable gas sand wherein the pool is underlain by or surrounded by water. Depending on the degree of uniformity and continuity of the formation beyond the edges of the pool, it may be expected, from theory, that the augmented water drive will be found almost as uniform in its encroachment pattern as an ideal natural water drive would be. In one Louisiana pool being considered, the operation would permit the operators to obtain income from the sale of the gas instead of being obliged to cycle to maintain pressure. At the same time pressure maintenance is possible at a lower cost. It is likewise believed that, inasmuch as the formations in the Louisiana pool is unusually uniform in permeability, greater recoveries can be obtained by induced water drive.

The principle of the technique has been described as a combination simultaneously of secondary and primary methods. An important difference between the methods is found in the amounts of water required ultimately for individual injection wells. Pressure-maintenance wells are scheduled for volumes up to 50,000,000 bbl. and are required to retain their capacities to take water for 30 years or more. Typical water-injection wells in the Bradford field receive 70,000 bbl. over a 7-year period. Before the quotas have been all injected, the capacities to receive water are frequently found reduced to one-fourth of the original. Inasmuch as high and sustained capacities are required in pressure-maintenance projects, considerable attention to injection conditions is required. Among factors to be controlled are: well completion, control of swelling of clay minerals, and compatibility of the waters to be mixed. Clear water is a requisite.

Although water drive is widely advocated, there are important instances[6] where gas-cap injection could prove more advantageous. Each pool requires study as early as possible. This would be facilitated first by drilling with wide spacing to define the pool boundaries, then by producing for a period at rates controlled to some extent by engineering requirements. This plan would provide suitable data for predicting results of various exploitation procedures. Thus, factual data will be made available early; and, if wide spacing is to be satisfactory under the procedure accepted, additional drilling can be avoided.

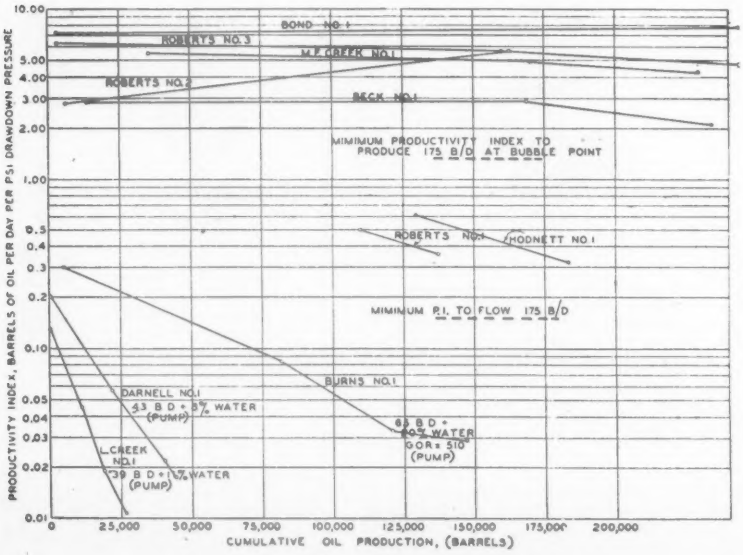


Fig. 5—Production and drawdown data, Midway field, Arkansas

Acknowledgment

The effective assistance of the Arkansas Oil and Gas Commission is gratefully acknowledged. Invaluable operating aid was rendered at Midway by employes of Barnsdall Oil Co.—especially H. D. Jones; R. B. Chesney; L. C. Carner; and V. B. Harris, petroleum engineer and foreman for the joint project.

References

1. W. L. Horner and D. R. Snow, "A New Application of Water Injection for Maintaining Pressure and Increasing Natural Water Drive," Drilling and Production Practice, 2-34 (1943).
2. W. A. Bruce, "A Study of the Smackover Limestone Formation and the Reservoir Behavior of Its Oil and Condensate Pools," Am. Inst. Mining Met. Engrs. Petroleum Development and Technology, 88-119 (1944).
3. Arkansas Oil and Gas Commission Factual Data No. 33, El Dorado, Ark., July 21 (1943).
4. Arkansas Oil and Gas Commission Order No. 2-39, Rule C-8, pursuant to Act No. 105 of the 52nd General Assembly of the State of Arkansas.
5. M. L. Euwer, "Salt-Water Injection for Pressure Maintenance," The Oil and Gas Journal 44 [21] (1945).
6. H. H. Kaveler, "Engineering Features of the Shuler Field and Unit Operation," Am. Inst. Mining Met. Engrs. Petroleum Development and Technology (1944).

No. 1 of a Series

Cementrol*

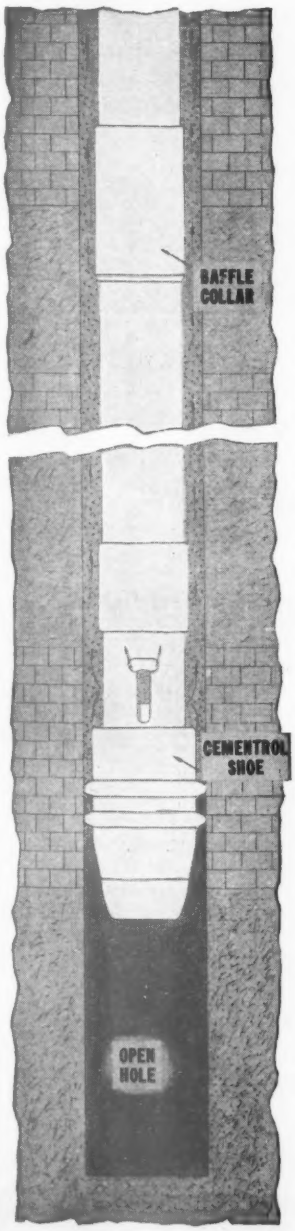
Your Positive Means of Protecting Permeable Low Pressure Producing Zones Immediately Below Casing Seat

CEMENTROL was designed and developed at the request, and with the assistance of oil producers who were encountering cement contaminated formations and impaired productivity in wells where casing had been cemented in the conventional manner above exposed permeable low pressure formations.

Its application in preventing this particular well completion difficulty is illustrated at the left.

The CEMENTROL shoe serves as a float shoe, a casing bridge and a packer, and is operated by pump pressure after casing has been landed at cementing depth.

A folder giving complete details on the operation of CEMENTROL will gladly be furnished upon request.



LARKIN PACKER CO., INC.

ST. LOUIS, MO.

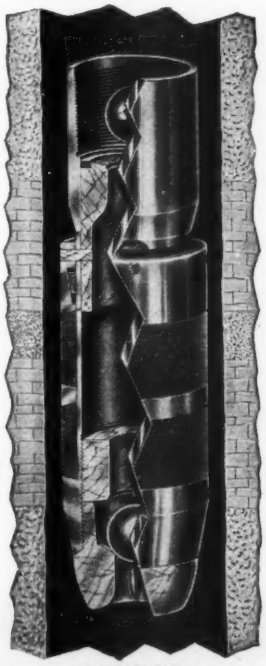
WAREHOUSES:
Tulsa
Houston
Great Bend
Wichita Falls
Odessa
Shreveport
Corpus Christi

LARKIN

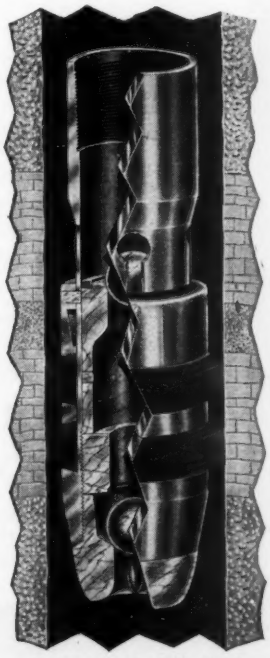
WEST COAST
Howard Supply Co.

ROCKY MOUNTAIN
E. C. Dilgarde Co.

EXPORT
19 Rector Street
New York 6

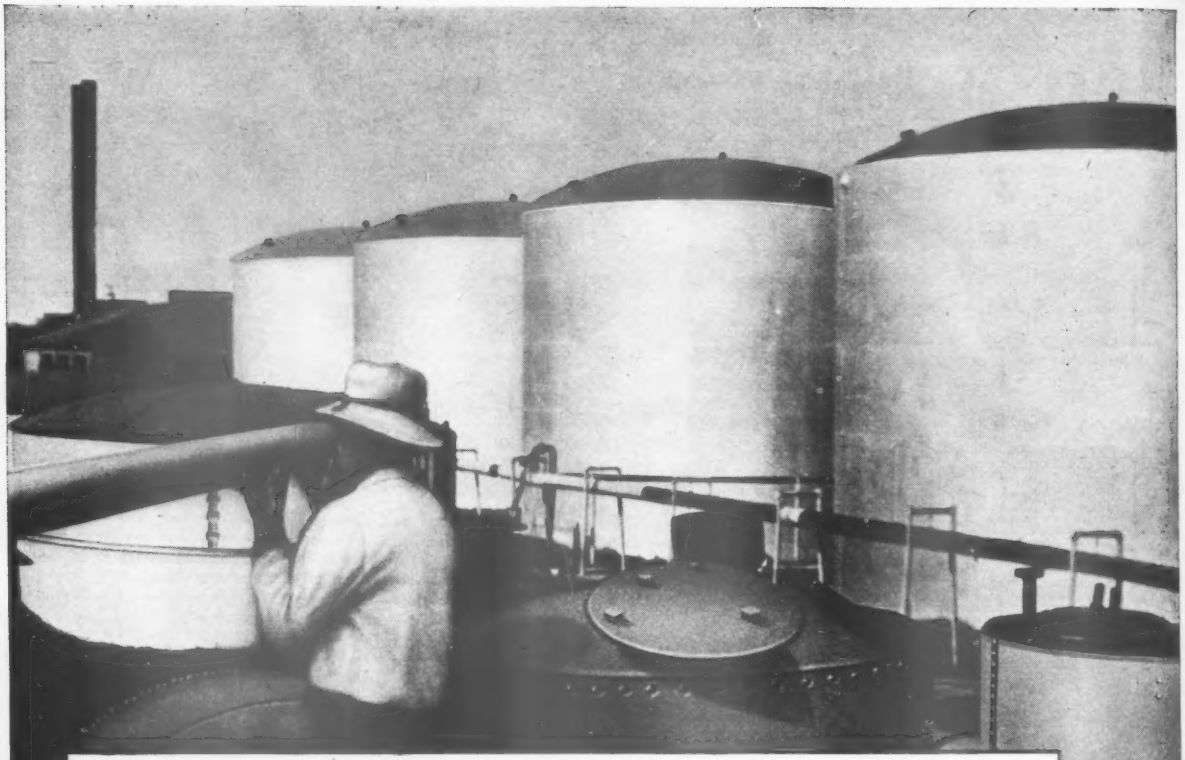


CEMENTROL Shoe, running-in position



Packer set, casing bridged, side cementing ports exposed

* *Reg. U. S. Pat. Off.*



Use This Terminal as Your Own Without Investment on Your Part

You can ship your material to General American terminals one car at a time or by the trainload—leave it in storage until you accumulate full cargoes or withdraw it in small quantities.

General American's skilled men are on the job day and night—saving you demurrage charges, helping you meet shipping dates. In General American terminals you have speed, you have safety, you have all benefits of your own terminal—without a penny's investment on your part.

GATX GENERAL AMERICAN

GENERAL AMERICAN TANK STORAGE TERMINALS

Goodhope and Westwego, La., (*Port of New Orleans*)
Carteret, N. J., (*Port of New York*) • Corpus Christi, Texas
Galena Park, Texas (*Port of Houston*)

Six Exclusive General American Advantages for YOU:

1. **STRATEGIC LOCATIONS.** Low rail and ocean freight rates.
2. **RELIABLE CUSTODIANSHIP.** Our warehouse receipts are highest type of collateral everywhere.
3. **INDEPENDENT OWNERSHIP.** Strict privacy. We do not buy, sell, or refine oils.
4. **MODERN PROTECTION.** Latest safety appliances; lowest insurance rates; minimum evaporation losses.
5. **LARGE TANK CAR FLEET**
6. **NO CONTAMINATION.** Separate pumps, lines, storage zones for dissimilar commodities.

A Division of General American Transportation Corporation

Injection of Water Into Underground Reservoirs in Michigan

*by W. E. Schoeneck**

A.P.I.

ABSTRACT

Injection of water in Michigan has been solely for the purpose of disposal, but regulations have been such that in excess of 90 per cent of oil-field waters are returned underground. The paper discusses the types of equipment used in injection wells and disposal systems, as well as describing the injection characteristics of each of the seven different formations employed for disposal purposes. Statistics on injection wells by years and by formations are detailed and summarized.

INTRODUCTION

THIS study of water injection into underground reservoirs in the state of Michigan is made by the author as a member of the A.P.I. Eastern District Production Technology Committee. It is stated at the outset that, with one exception, there is no record of water injection in the state of Michigan having been performed for the expressed purpose of secondary recovery of oil but, rather, that the primary purpose of all wells and projects investigated has been for the disposition of water into underground reservoirs in order to prevent pollution of lands, surface waters, and shallow water wells. The sole exception was the periodic injection of small quantities of water in conjunction with a gas-injection program in the Greendale field. This was done in one well for a period of approximately 3 weeks in 1932.

The source of information for this study has been semiannual and special reports of the oil and gas division of the Michigan Department of Conservation, from personal contact with the employes of this department and with the personnel of operating companies, and from general experience in this state.

The purpose of this study is to compile all the available statistical information pertinent to water injection in Michigan, to analyze these data in order that significant conclusions might be reached, to describe sufficiently the physical injection and its inherent problems, in order that all such facts will be available for the use of Michigan oil operators and the industry as a whole.

History of Water Injection

The tourist trade is the second largest industry in Michigan, and for that reason the Department of Conservation in this state has paid particular attention to the matter of prevention of stream pollution resulting from the disposition of oil-field wastes into surface waters. An excerpt from the "general rules and regulations" governing oil and gas operations in the state of Michigan, effective May 1, 1941, best explains the attitude of this department, and is as follows:

"Brine or salt water produced in the drilling for, or the production of, oil shall not be run to earthen reservoirs or ponds, except for such reasonable time and under conditions as may be approved by the supervisor, or his authorized representative, after which it must be returned to some underground formation or otherwise disposed of as approved by the supervisor where it cannot do damage to any fresh water, oil, gas, or other minerals."

It is for this reason that the oil and gas industry in Michigan in recent years has had such an enviable record in returning underground in excess of 90 per cent of the oil-field water produced, the balance going to ponds constructed for storage. Reference is made to Fig. 1 which illustrates graphically total oil production in the state by years from 1930 through 1944, together with the total yearly water injected during this period. It is noteworthy that during 1937 and 1938 the total water injected was equal to half the total oil produced, whereas currently total water injected is equal to 1½ times the oil produced. Total water injected underground to midyear 1944 is in excess of 150,000,000 bbl.

Fig. 2 is a generalized transverse

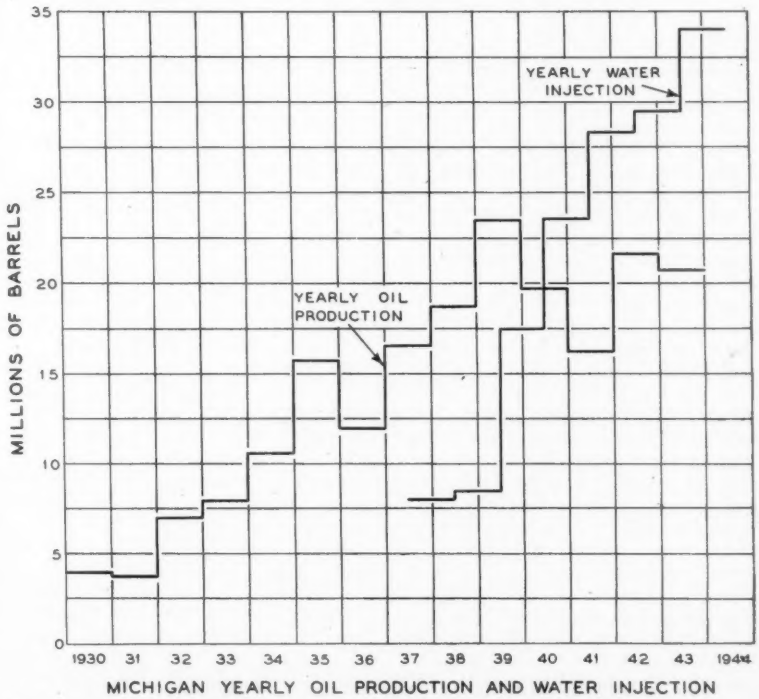


Fig. 1

*The Ohio Oil Co., Grand Rapids.

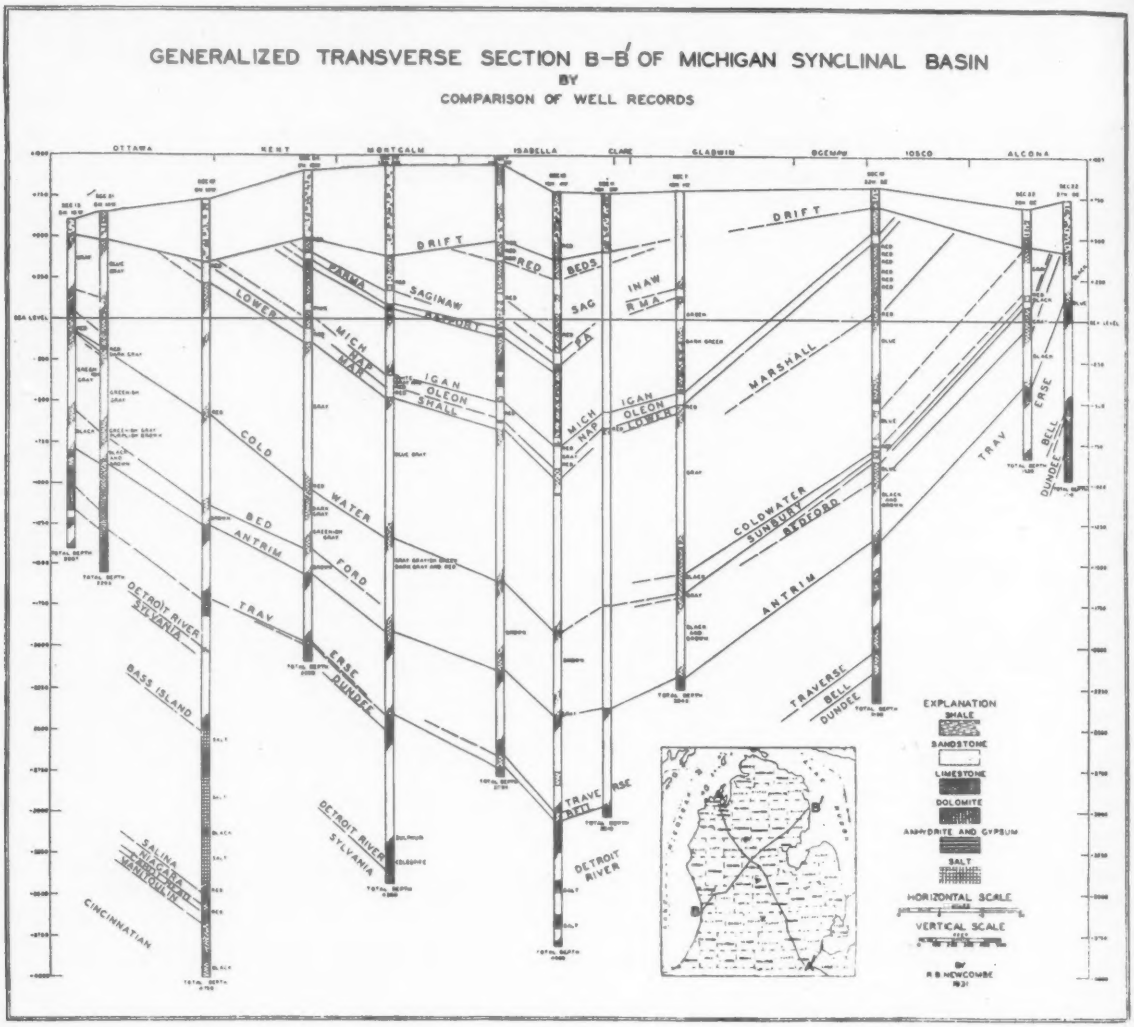


Fig. 2

section of the Michigan synclinal basin from which area the majority of the oil is produced and into which area all of the water is injected. This figure illustrates the approximate thickness and depth of the formations which are used for water disposal, viz., the Drift, the Parma, the Marshall, the Coldwater, the Traverse, the Dundee-Monroe, and the Sylvania.

Table 1 (deleted from this reproduction) lists water-injection wells by fields and indicates: the formation or formations into which each well is opened, the type well, the estimated cumulative injection to June 30, 1944, the 1944 approximate daily rate of injection, and whether or not the well operates on a pressure or vacuum. A search of the records reveals that there was little information available on water injection previous to 1937, notwithstanding the fact that there were probably a few water-injection wells in existence previous to that time. Therefore, the total cumulative injected barrels contained in this report include no water previous to 1937. It is to be appreciated that the water-injection volumes were prepared from semiannual estimates of the daily average injection as of July 1 and January 1. Naturally, a change in method of operation would involve errors in the calculation of these total quantites, but it is believed that these errors are sufficiently compensating to make the totals a reliable estimate.

Table 2 is a summary of statistical data revealing by years: the number of wells, the daily average rate of injection, and the yearly total injection in the different types of wells used for water disposal. Table 3 is an analysis of 1944 injection, showing for each injection formation: the number of wells, and the total yearly injection for 1944, with a breakdown as to the wells operating by pressure or by gravity. Further analysis reveals the percentage of the total number of wells and percentage of the total water injected, as well as the average rate of injection for each respective formation.

Description of Operations

Well completion and operation.—There are three general classifications of disposal wells insofar as the mechanics of completion and operations are concerned: (1) Wells which inject water into the annular space between casing strings; (2) wells which were originally dug in search for or were used for production of oil and gas and were later converted to water-disposal wells; (3) wells which were dug for the specific purpose of water injection.

Table 2 illustrates that, although there have been 316 wells which injected water between the casings and 120 which have been completely converted to water disposal, the former type wells have contributed

. . . so you want corrosion resistance

for service piping and pressure vessels

. . . Well, we cannot blame you for this, as it is one of the big problems of plant managers and water service engineers. It is usually oxygen and other gases in the water that help to cut down the working life of piping and vessels. A complete water treatment service, such as Nalco offers, is one way to eliminate this trouble once and for all.

Nalco has made corrosion, scale, foaming, algae and the many other ills which accompany untreated or *improperly treated water* a thing of the past. It can do the same for you—ask for a Nalco survey today. There is no obligation.

Photo in Nalco Laboratories

L. L. Simpson
Nalco Representative,
Omaha, Nebraska

THE SYSTEM OF SCIENTIFIC WATER TREATMENT FOR THE PETROLEUM INDUSTRY

NATIONAL ALUMIN[illegible] CORPORATION
6242 W. 66th Place [illegible]38, Illinois
Canadian inquiries should be addressed to Aluminate Chemicals, Ltd., 55[illegible] Toronto, Ont.

nalco

NEW CONSTRUCTION . . . alteration . . . dismantling . . . re-erection . . . of anything from a stack to a complete refinery . . . those are the jobs that Graver Construction Division is doing today to speed the gigantic reconversion program . . . to keep men at work.

The broad experience, trained personnel, and modern equipment of this organization are available to you . . . now. Let us quote on your next job.

Construction Division of

GRAVER TANK & MFG. CO., INC.

4811-51 Tod Ave., East Chicago, Ind.

New York Catasauqua, Pa. Chicago Tulsa, Okla.
Philadelphia Port Arthur, Texas

GRAVER
CONSTRUCTION
DIVISION

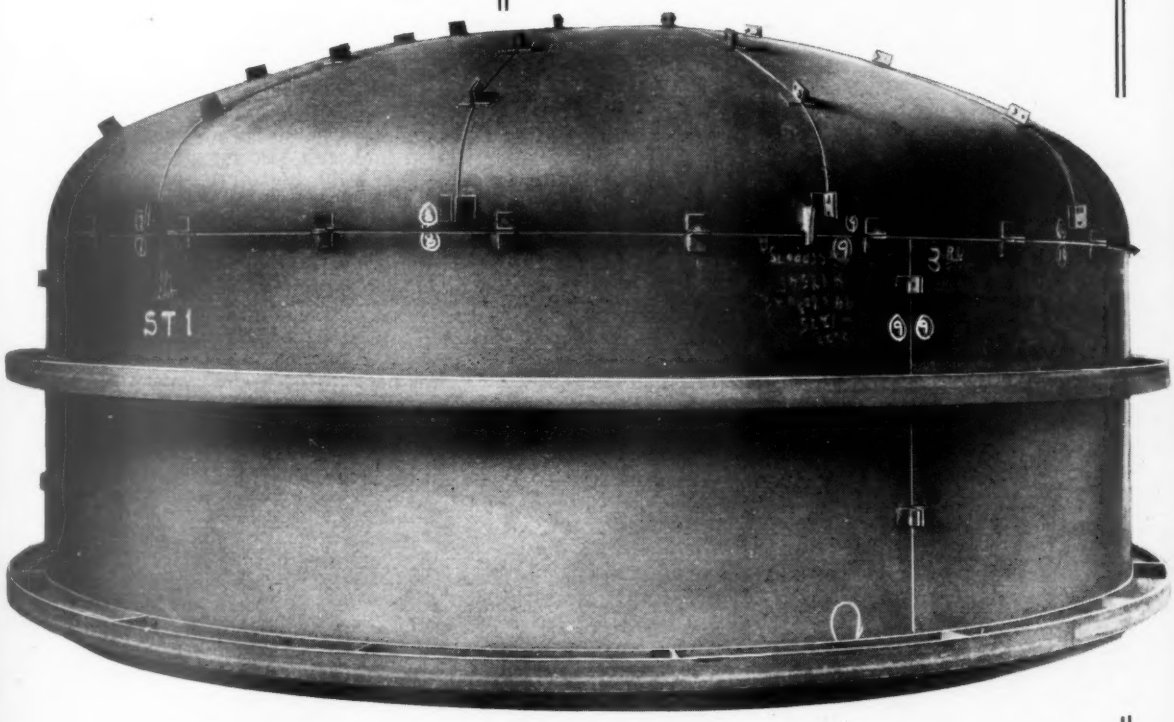
XUM

TOPS...
in steel plate fabrication

THE knack of working closely with our customers . . . the ability to understand their problems and their needs . . . the knowledge that comes only with years of experience . . . and the equipment with which to handle each operation with the greatest efficiency and economy . . . have all combined to earn for Graver a national reputation for "Tops in Steel Plate Fabrication."

With these few words we declare the standard of perfection to which we are committed and which we pledge to maintain. And it's good to bear this in mind when you are in the market for any type of fabricated steel plate equipment.

Send us your blueprints. We'll submit cost estimates promptly.



Dome top for a 125,000 gallon Hot Process Water Softener built by Graver

GRAVER
FABRICATED STEEL PLATE EQUIPMENT

Fabricated Steel Plate Division
of
GRAVER TANK & MFG. CO., INC.
General Offices: 4811-13 Tod Ave., East Chicago, Ind.
New York Chicago Catasauqua, Pa. Tulsa, Okla.
Philadelphia Port Arthur, Tex.
EXPORT DEPT.,
424 MADISON AVE., NEW YORK, N. Y.

TABLE 2—SUMMARY OF STATISTICAL DATA ON SALT-WATER INJECTION
(Quantities of Water Shown in Barrels)

Wells using angular space between casings:	July 1937 to July 1938	July 1938 to July 1939	July 1939 to July 1940	July 1940 to July 1941	July 1941 to July 1942	July 1942 to July 1943	July 1943 to July 1944	Totals for 1937-1944 Inclusive
No. of wells	61	57	81	124	186	185	178	316
Daily rate	12,392	11,873	19,326	20,921	24,112	25,876	22,248	
Yearly total	4,523,080	4,333,645	7,053,990	7,636,165	8,800,880	9,444,740	8,120,520	49,913,020
Wells converted for disposal:								
No. of wells	20	15	41	54	62	74	86	120
Daily rate	9,594	11,808	29,004	44,097	53,485	54,083	64,962	
Yearly total	3,501,810	4,309,920	10,586,460	16,095,405	19,522,025	19,740,295	23,711,130	97,467,045
Wells drilled for disposal:								
No. of wells	..	..	..	4	4	6	15	18
Daily rate	0	..	0	283	116	830	6,332	
Yearly total	..	..	..	103,295	42,340	302,950	2,311,180	2,759,765
Totals:								
No. of wells	81	72	122	182	252	265	279	454
Daily rate	21,986	23,681	48,330	65,301	77,713	80,789	93,542	
Yearly total	8,024,890	8,643,565	17,640,450	23,834,865	28,365,245	29,487,985	34,142,830	150,139,830

a total of approximately 50,000,000 bbl. of water injected as compared to a total of 97,000,000 bbl. for converted wells. There have been only 18 wells dug specifically for the purpose of water disposal, and the total water injection into this type of well has been less than 3,000,000 bbl. to date. In view of the fact that there are so many disposal wells in the state injecting water between strings of casing, it would be helpful perhaps to mention briefly the method of well drilling and the casing program in order that this type of injection may be more understandable.

The thickness of the glacial drift in Michigan varies from 100 to 1,100 ft. A great percentage of the wells are drilled with cable tools, and in such cases surface casing is generally driven completely through the Drift. Many, although not all, of the cable-tool wells set a permanent intermediate casing string. Most production strings are set on a shoulder with a packer, and without the use of cement. Surface casing in rotary-drilled holes is set from 100 ft. in the Drift to the base of the Drift. Both intermediate strings, when used, and production casing strings are cemented in the rotary holes. The resulting casing programs in both cable-tool and rotary wells make available the annular spaces between the surface casing, the intermediate casing, and the production casing, for water disposal to any of the several formations which are usable for this purpose.

Wells converted for salt-water disposal may use the formation in which they were originally completed, may have been deepened to other horizons, or may have been perforated in shallower permeable zones. Wells dug specifically for the purpose of salt-water injection have been dug to the Drift, to the Parma, but no deeper than to the Marshall formation.

Injection equipment.—There is no record of either chemical or physical water treatment in disposal plants other than the use of sufficient skimming tanks to separate oil from water, and the use of oil seals to prevent the contact with air from the time of production to the time of injection. Steel pipe, either new or used, is employed in gathering lines for the transportation of salt water in the vast majority of cases. This does not mean to imply that the Michigan salt water, or brines as they are commonly termed, are noncorrosive; for there is evidence of corrosion in all types of equipment associated with salt-water disposal. However, the life of the properties has been relatively short, and apparently operators have not taken pains to install non-ferruginous materials. In later years there have been several installations of Transite lines to eliminate the corrosion problem.

Referring to Table 3, of the total of 279 wells in operation during 1944, 194 took water by gravity and 85 required pressure for the disposal of water. In the majority of cases pressure is furnished by pumps connected to the walking beam of the producing wells. This is particularly true in the case of scattered operations or small volumes of water. A larger concentration of operations, or larger quantities of water, are generally served by seperately powered and centrally located pumps installed for use in conjunction with a disposal pipeline system.

Well treatment.—The contaminating materials resulting from inadequate physical or chemical treatment of the water which cause the plugging of injection wells are principally carbonates, iron oxide, salts, and paraffin. There has been an appreciable amount of trouble from these several contaminating agents which periodically reduce the ability of injection wells to take water. However, it is generally believed in Michigan disposal operations that, considering the over-all picture, it is cheaper to treat wells after they have become partly contaminated than it is to prevent con-

TABLE 3—ANALYSIS OF 1944 INJECTION
(Quantities of Water Shown in Barrels)

Injection formation	Wells injecting by gravity	Wells injecting by pressure	Totals	Per cent of total wells	Per cent of total injection	Average rate of injection (barrels per well per day)
Drift:						324
No. of wells	5	2	7	2.5		
Yearly total	128,845	701,165	830,010		2.4	
Parma:						149
No. of wells	84	24	108	38.7		
Yearly total	2,527,625	3,360,920	5,888,545		17.2	
Marshall:						148
No. of wells	9	5	14	5.0		
Yearly total	374,490	382,155	756,645		2.2	
Coldwater:						96
No. of wells	23	38	61	21.9		
Yearly total	607,360	1,540,300	2,147,660		6.3	
Traverse:						317
No. of wells	32	10	42	15.1		
Yearly total	3,071,840	1,795,070	4,866,910		14.3	
Dundee-Monroe:						1,320
No. of wells	38	0	38	13.6		
Yearly total	18,306,575	0	18,306,575		53.6	
Dundee and Parma:						1,025
No. of wells	2	0	2	0.7		
Yearly total	748,250	0	748,250		2.2	
Parma and Drift:						234
No. of wells	1	6	7	2.5		
Yearly total	40,150	558,085	598,235		1.8	
Totals:						335
No. of wells	194	85	279	100.0	100.0	
Total injection	25,805,135	8,337,695	34,142,830			

Baash-Ross News

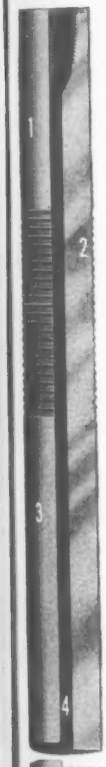
BAASH-ROSS TOOL COMPANY · LOS ANGELES · HOUSTON · NEW YORK

OUR 25th YEAR

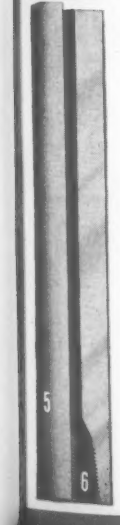
EVER WONDER WHAT MAKES THE BIG DIFFERENCE IN DRILL COLLARS?

. . . AND HERE'S HOW BAASH-ROSS BUILDS THAT EXTRA PERFORMANCE into TRUBORE DRILL COLLARS

Here's WHAT you get in the Baash-Ross "Trubore"



1. ***Hard Wear Resistance*** to withstand abrasion from constant rotation against the sharp fresh-cut walls of the hole.
2. ***Tough Shock-Resistance*** to withstand the strains and stresses of heavy-duty, high-speed drilling service.
3. ***Double Heat Treated Body*** that *stays* straight and balanced because all residual stresses are relieved by *two* full-length heat treatments.
4. ***Exactly-Centered Bore Hole*** that assures better balance, turbulence-free circulation and smooth passage of wire line tools.
5. ***Hardened End Sections*** through extra heat treatment for long-wearing thread sections (Brinell 285 to 310!)
6. ***Precision Joint Alignment*** that minimizes "working" of joints and break-off hazards in tandem drill collar strings.



"Trubore" Drill Collars are available in a wide variety of patterns . . . in sizes ranging from 2⅞" to 6⅝" . . . in API Regular, API Full Hole and Internal Flush types . . . and in lengths to as long as 60 ft. in the most popular sizes. Also other sizes on order. There's a "Trubore" for your job. Write, outlining your particular need!

THROUGH long years of specialization in the manufacture of highest quality drill collars, Baash-Ross has developed advanced and unique methods of boring, threading, heat-treating and testing "Trubore" Drill Collars. Here are a few highlights of the many operations that put the *extra* performance into "Trubore" Drill Collars . . .

Careful Selection of Steels: To get a tough shock-resistant body coupled with wear-resisting hardness to withstand constant rotation against the abrasive walls has required years of careful study by Baash-Ross engineers. "Trubore" Drill Collars are made only from selected fine-grained alloy steel forgings, with discs from each end of every forging individually etched and laboratory checked to insure maximum qualities.

Double Full-Length Heat Treatments: After forging, there are many unrelieved stresses and irregularities in the drill collar that could cause warping and bending in service. So in this giant furnace, Baash-Ross Drill Collars are heated in one operation over their full length to

a temperature above the upper limit of the critical range, held at that temperature until full heat penetration is assured, then cooled in still air. *Again* they are heated in one operation over their *full* length to a temperature below the critical range, held for uniform heat penetration and cooled in still air. This *double* full-length heat treatment relieves all residual stresses so that the Drill Collar *stays* straight and warp-free under the most severe field service.

Additional Heat-Treatment of Thread Areas: After the double full-length heat treatment, Baash-Ross gives a *third* heat treatment to the ends, then oil-quenches and draws them to a Brinell of 285-310 for a distance of at least five feet from each end. Each end is then individually Brinell-checked to assure maximum thread life and service.

Accurately Bored Circulation Hole is a feature of such unique importance that it has given the name "Trubore" to Baash-Ross Drill Collars. A special process is employed by Baash-Ross to drill the hole unusually straight and closely centered end to end. In fact, the bore is so carefully drilled that it does not deviate more than ¼" in 40 *feet*

from theoretically perfect. That's precision commercial boring! And the bore accuracy of each drill collar is individually checked by the special high-precision survey equipment shown here . . . As a double check a ten foot test bar with diameter not less than ⅛" smaller than bore must pass freely through without binding!

Accurate Joint Alignment: The straightness of "Trubore" is held to within ⅛" of true at any point over the entire length. But such straightness is of full value only if the joints are exactly aligned to prevent "working" and bending stresses at the joints. So after machining the threads in special equipment, this unique survey instrument is screwed into the threads to check alignment. To

pass this inspection the projected axis of the joint with respect to the nominal axis of the drill collar must be within ½" in 40 feet.

Space does not permit details on other important steps in making "Trubores," but your Baash-Ross representative will gladly supply complete information. Also see pages 252-253 of your Composite Catalog . . . or write direct for additional information!

XUM

tamination by installation of complex and comparatively expensive water-treating equipment.

There are four different methods of well treatment or repair which are generally applied to water-injection wells in this state. They are, in order of their general importance: acid treatment, application of pressure, fresh-water injection, and lye-solution injection.

Acid treatments, varying in concentration of hydrogen chloride from 15 to 30 per cent, have been extremely successful in increasing the effective permeability of limestone-injection wells by either dissolving the reservoir rock, dissolving the contaminating material, or both. No accurate records of the frequency of this type treatment are available, but the acid service company most generally employed for this work in the state reports in excess of 30 acid treatments per year from 1940 through 1944. In addition to these treatments, a considerable quantity of bulk acid has been sold to operators injecting their own acid with lease equipment. In many cases it is the practice to repeat acid treatments on certain wells at not infrequent intervals, thereby periodically increasing the capacity of the well to meet requirements.

Pressures, generally not in excess of 1,000 psi. at the surface, are applied to wells which have experienced a decline in injection rate, and results have been sometimes quite successful. Pressures so applied to limestones and the unconsolidated sands of the Drift break down any film of contaminating materials that may be against the permeable portion of the formation.

The injection of fresh water to dissolve water-soluble salts has been used with some success, and is often done just previous to an acid treatment.

It is reported that well treatments have been effected by the injection of a solution of ordinary lye, but little is known of the results.

Description of Disposal Formations

Glacial Drift.—The Glacial Drift covers practically all of the state in which there exists the problem of salt-water disposal. The Drift is an unconsolidated formation varying in thickness from 100 to 1,100 ft. containing sands, gravel beds, boulders, and clay. This formation generally contains water which may be potable at any depth, although normally it has sufficiently high salinity at its base to be unsuitable for domestic or commercial uses, and it is, therefore, sometimes employed for water disposal. The unconsolidated nature of this formation makes well completion for disposal a relatively difficult procedure, but the method of setting casing through the Drift and gun perforating have proved relatively successful. Perforating with ⅛-in.-diameter bullets has recently been tried to prevent sanding-up of these wells. When disposal is effected into this formation between strings of casing, it is always unknown as to just how much of the formation might be exposed or, rather, how much of the formation has caved or bridged.

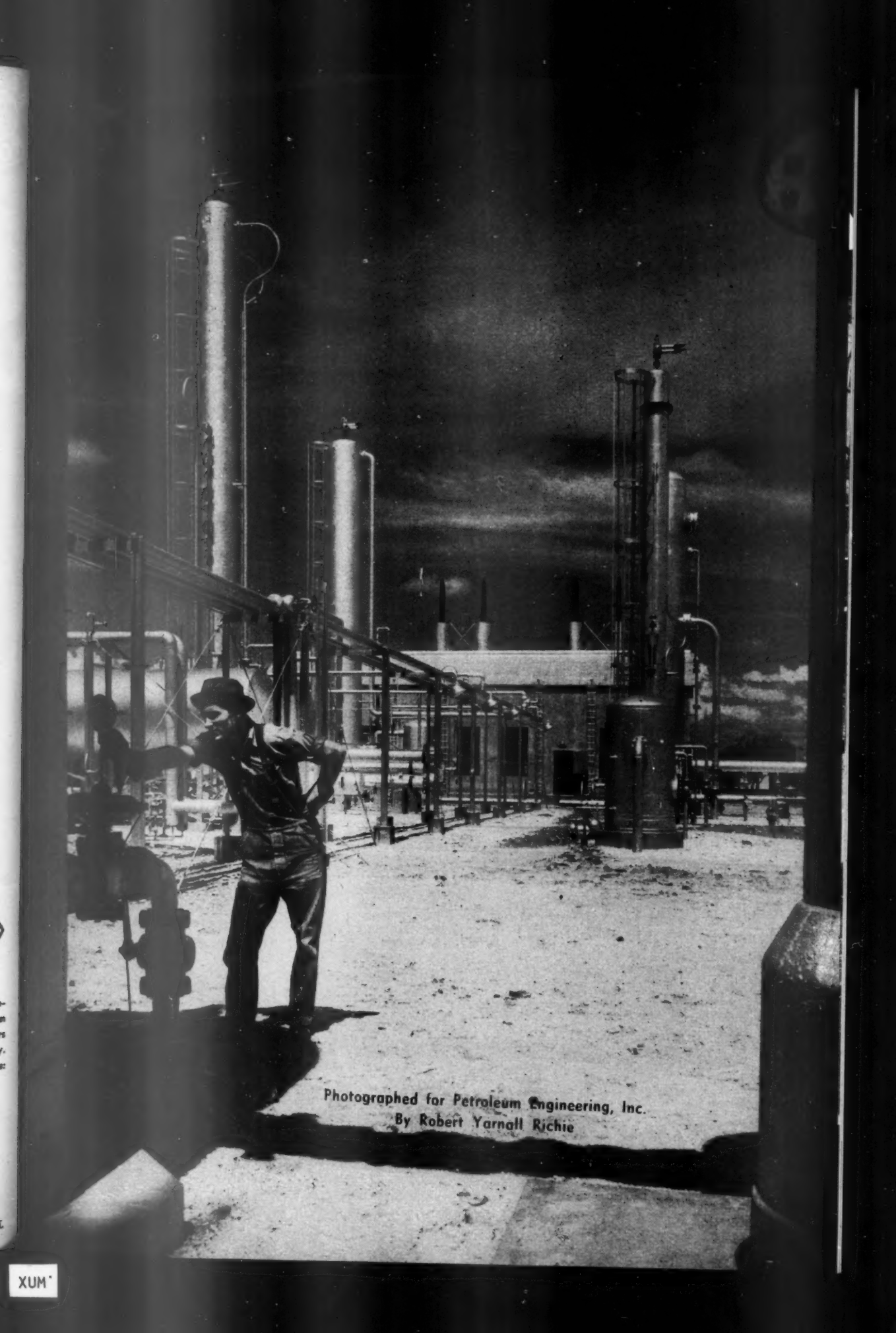
Parma.—Notwithstanding the current use of the Parma formation in 108 disposal wells, a limited number of cores from this formation do not indicate that it would lend itself readily to water injection. This formation is generally a relatively impermeable sandstone with some carbonate cementing material which responds to acid treatment in some areas. The number of disposal wells in this formation is 38.7 per cent of the current total in operation, but these wells contribute only 17.2 per cent to the total injection of water —which fact would tend to confirm the mediocrity of this formation for injection.

Marshall.—The Marshall formation consists of relatively thick sands interbedded with shale. This formation has not been used a great deal because of its relative depth and its proximity to the Michigan Stray gas sand which it immediately underlies; i.e., sufficient protective measures for the Michigan Stray must of necessity be taken where it is gas-bearing, and the use of the Marshall for water disposal has been generally precluded in such areas.

Coldwater.—There are a total of 61 disposal wells which inject water into the Coldwater lime, the porous lime member in the basal part of the Coldwater shale formation. All of these wells are located in southwestern Michigan, and all water disposal into this formation is in the annular space between casings. These wells represent 21.9 per cent of the current total number of wells, but contribute only 6.3 per cent to the total water injected. Disposal into the Coldwater formation has been by gravity when quantities less than 100 bbl. per day are injected; whereas pressure is generally required for quantities in excess of 100 bbl. per day. Acid has been used in most of these wells with good results. Some of these wells have required pressure during the initial period of injection, later breaking down and taking water by gravity. Water in the Coldwater formation has been found to be fresh in some areas in southwestern Michigan.

Because of the setting of surface casing above the base of the Drift in some wells, and the destruction of drive-pipe casing seats at the base of the Drift as a result of injection breakdown pressures as high as 600 psi., there is the probability

A view of one of many plants designed and constructed by Petroleum Engineering, Inc., in the past 16 years of continuous service to the industry. Petroleum Engineering, Inc., Offices: Tulsa and Houston.



Photographed for Petroleum Engineering, Inc.
By Robert Yarnall Richie

XUM

that at least a portion of the water allocated to the Parma, Marshall, and Coldwater formations is actually going into the base of the Drift formation. Just what percentage of this water finds its way to the Drift is naturally unknown, but mention is made of the fact in order that the quantities allocated to these other three formations might be qualified to forestall any misrepresentation of the ability of these formations to take water.

Traverse.—The available permeable lime members of the Traverse formation readily lend themselves to water disposal. Generally, there exists a lime bed in the upper portion of the formation which may or may not be sufficiently permeable for water injection. At greater depths in this section the limes may or may not be present. It should be noted that the ability to find a permeable lime in the Traverse formation will not only vary from field to field, but from location to location—which fact distinctly lowers the desirability of this formation as a potential water-disposal horizon. Notwithstanding, in fields where the permeable zones have been found, they have a great potential capacity for disposal. There are, as of mid-1944, 42 Traverse disposal wells in the state which are returning during the year 4,800,000 bbl., or 14.3 per cent, of the total water. It is to be noted that of the total of 42 wells presently in operation, 32 take water by gravity. The significance of this is that Traverse wells are used for disposal principally in fields which have Traverse production, and most generally there will be some degree of pressure decline within these reservoirs. This results in a progressively lowering static fluid level in injection wells, affording a greater height to the injected column of water, with the resulting advantage that there is available for injection increased pressure at the formation.

Dundee-Monroe.—The Dundee and Monroe formations have been grouped together, and include the porous members of the limestones and dolomites below the base of the Bell shale. The Monroe formation is designated on the generalized transverse section as the upper part of the Detroit River formation. These zones are presently being used in 38 water-injection wells (13.6 per cent of the total), and have contributed 18,000,000 bbl. injected, which represents 53.6 per cent of the total for 1944. As in the case of the Traverse formation, the wells which are used for disposal in the Dundee-Monroe exist in fields which are producing from these formations and enjoy the same benefits of declining reservoir pressures. All of these 38 wells are operated by gravity.

Sylvania. — Only two wells are known to have been open to the Sylvania formation for water injection and, therefore, adequate information on this horizon is lacking.

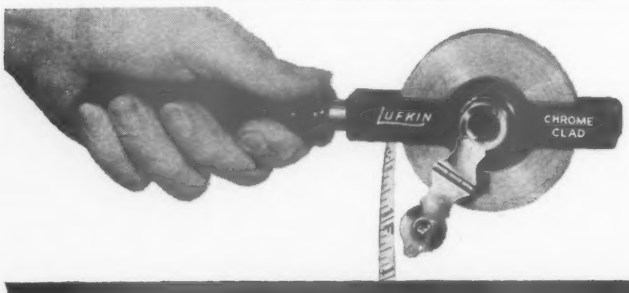
Summary

The unavailable portion of the early history of water injection in the state of Michigan does not represent a sufficiently high percentage of the data to make an appreciable difference in the total picture presented herewith. Water has been injected in sufficient volumes, and with sufficient variance of attendant conditions, to conclude that the information available can be a guide to future operations in Michigan, as well as an addition to the general information available on the subject of water injection.

Formations available for water injection in the state are numerous, and have proved adequate (with a minimum of expense) to dispose of the vast majority of the water incidental to the production of oil. It is noteworthy that, currently, half of the total number of wells in operation inject into a limestone, and that these wells contribute three-quarters of the present water injected. Attention is again called to the fact that the best available wells for injection are those completed in the same horizons as the oil-producing wells because of the advantage resulting from declining reservoir pressures. Capital cost of accessory equipment for injection has been comparatively low in the state, as has been the cost of equipment, maintenance, and well repair.

Acknowledgment

Acknowledgment is made of the kind assistance given by F. R. Frye, W. L. Daoust, K. G. Walsworth, L. W. Price, D. W. Conaway of the Michigan Department of Conservation; H. L. Donhaiser, The Pure Oil Co.; Lester LeFavour, Gulf Refining Co.; and L. C. Powell, The Ohio Oil Co., who aided in the compilation and analysis of the information.



JET BLACK MARKINGS ON SATIN CHROME

The heavy steel line of the Lufkin Chrome Clad Oil Gaging Tape is covered with a satin chrome "life jacket." This rust-resistant chrome coat means longer life and easier oil level measuring. Jet black markings are sunk below the line surface where they can't wear out. Oil level shows up clearly against this non-glare finish. Solid brass plumb bob. Case hardened steel frame. For easy, accurate measuring, use Lufkin Chrome Clad Oil Gaging Steel Tapes. Order through your supply house. THE LUFKIN RULE CO., SAGINAW, MICH., New York City.

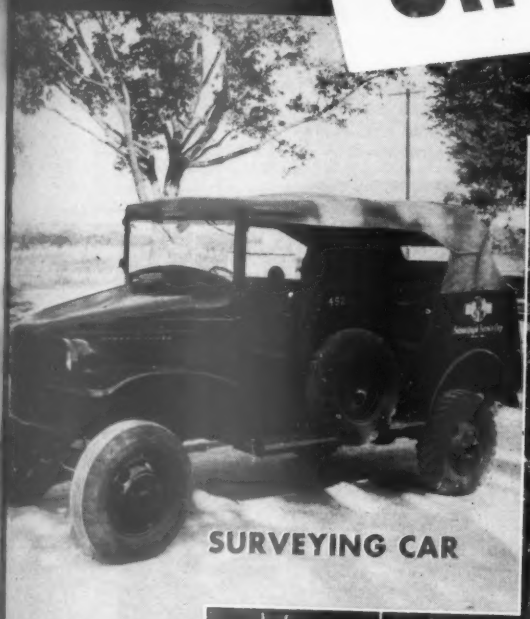
LUFKIN FOR ACCURACY

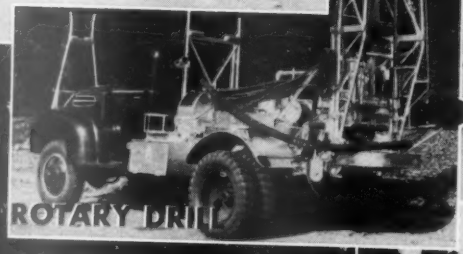
Bottom-Hole Water Will Be Analyzed

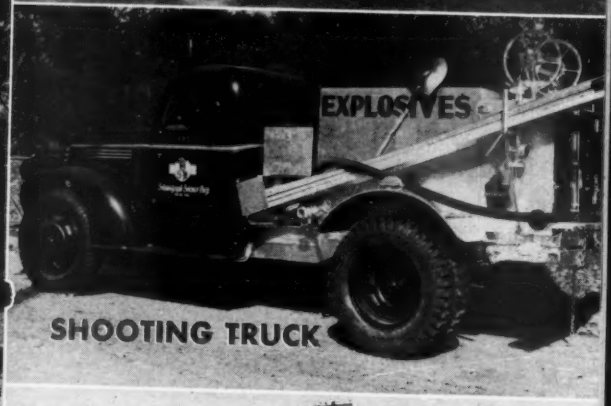
Samples of bottom-hole water from a dozen wells in the Oil City-Pleasantville (Pa.) area will be analyzed at Battelle Memorial Institute, Columbus, Ohio, in an effort to learn the cause and cure of corrosion in air-gas secondary-recovery oil-producing operations in the Pennsylvania Grade region.

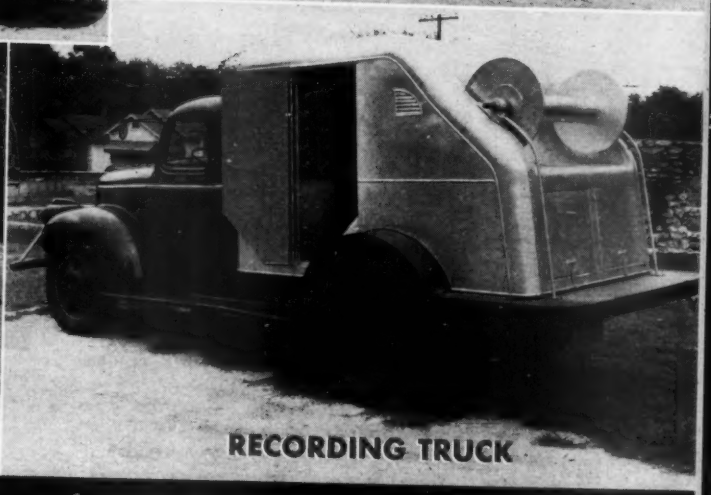
C. E. Stout, of Parkersburg, W. Va., production research engineer for the Pennsylvania Grade Crude Oil Association, has just completed collection of the samples. The work was done in conjunction with R. B. Bossler of Bundred Oil Corp., Oil City.

EQUIPMENT USED IN REVEALING Oil For Tomorrow









Seismograph Service Corporation

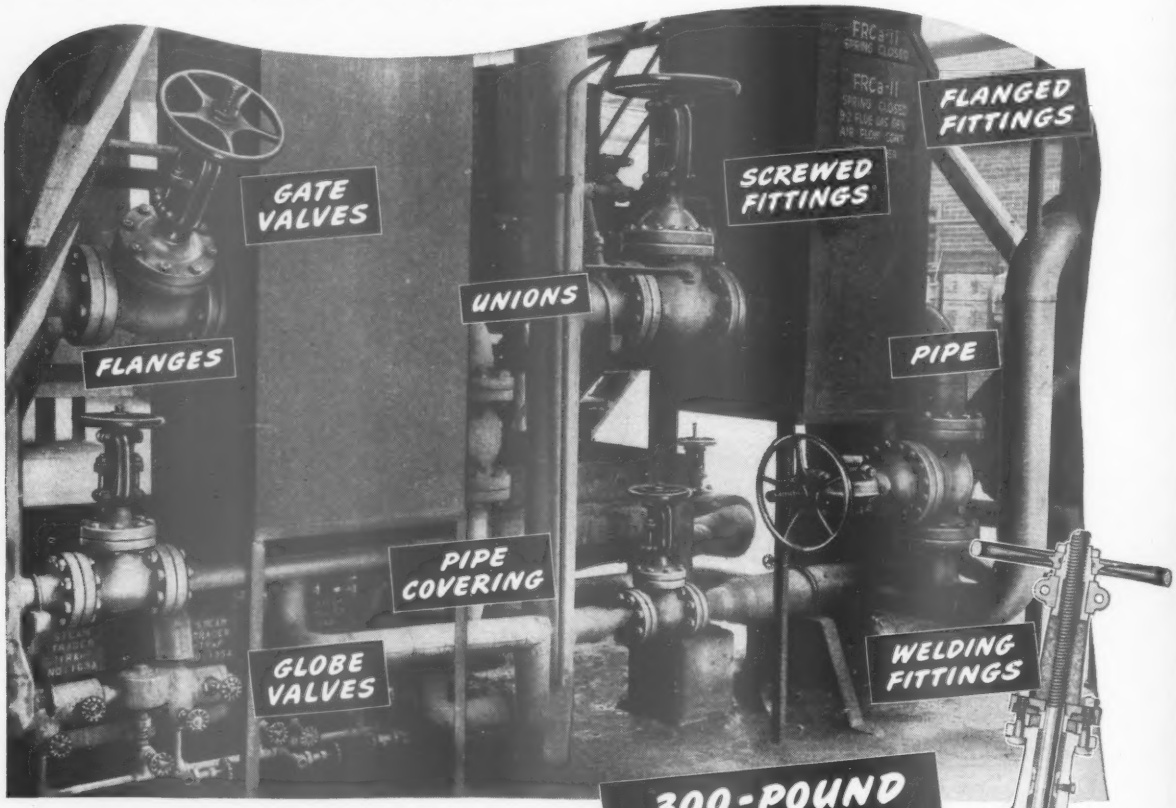
TULSA, OKLAHOMA, U. S. A.

For Every Problem in Piping Materials ...a CRANE Solution

To simplify and speed deferred replacement work, take advantage of Crane *complete* piping materials service. *All* your needs are supplied by a single source—your Crane Branch or Wholesaler. You choose from the world's greatest line of piping materials—in brass, iron, and steel—in all pressure-temperature classes. Uniform quality in all equipment—backed by single responsibility and 90 years' manufacturing experience—helps you get the best installations. You *know* your piping is at its best. Below is one example of a Crane solution to many of your gate valve requirements.

ONE STANDARD OF QUALITY
ONE RESPONSIBILITY
ONE SOURCE OF SUPPLY

Air control manifold for flue gas generator



300-POUND CAST STEEL WEDGE GATE VALVES

SERVICE RECOMMENDATIONS: **Crane Cast Steel Wedge Gate Valves** are made in all pressure classes up to 2500 pounds and for temperatures up to 1100° F. The 300-pound class, shown in cross-section, with Exelloy to Exelloy trim, are suited for all oil and oil vapor services up to 1000° F.; with Exelloy to No. 49 Nickel Alloy, for steam, water, gas, or air up to 850° F. maximum; and with Stellite to Stellite seating, for steam to temperatures up to 1000° F. Available with flanged or welding ends in sizes up to 24 in.; with screwed ends up to 4 in. See your Crane Catalog for complete specifications.

CRANE CO., General Offices: 836 S. Michigan Ave., Chicago 5, Ill. • *Branches and Wholesalers Serving All Industrial Areas*

CRANE

90 YEARS OF PROGRESS 1855 1945

VALVES • FITTINGS • PIPE
PLUMBING • HEATING • PUMPS

Behavior of Water-Input Wells

by Parke A. Dickey* and Kurt H. Andresen†

P. A. DICKEY

K. H. ANDRESEN

A.P.I.

ABSTRACT

The factors that affect the rate at which a water-injection well takes water are discussed. Theoretical formulas and examples of actual well behavior are given. Transient back-pressure phenomena in the reservoir are described. These phenomena have an important effect on the response of a well to changes in applied pressure. The concept of localized injectivity index, which is the conductivity of an individual input well, is introduced, and methods for its determination suggested.

The factors that affect adversely the efficiency of injection wells are described, and illustrations of actual well behavior are given. Among these the plugging of the sand by suspended or dissolved solids is important. A brief discussion of controlled plugging is also included. The effect of excessive pressure in causing rupture of the formations is described, discussed, and illustrated by examples of such ruptures.

Introduction

ALTHOUGH the basic formulas describing the radial flow of fluids in porous media have been in general use in oil-field engineering for several years, there are many features of actual well behavior that have never been discussed or described in published material. This paper is an attempt to describe certain of these phenomena which are important in connection with the injection of water into underground reservoirs. An attempt is made to relate the observations to the generally accepted theory. However, the explanations are considered tentative, and many more similar studies will have to be made before completely satisfactory explanations of input-well behavior are possible. This paper is in no sense a treatise on water-injection wells, but rather raises numerous problems on which further work is required.

1. General

Water is injected into underground reservoirs to supply artifically developed energy to partly depleted reservoir rocks and thus increase the rate of oil production or, in some fields, merely as a means of disposing of an annoying byproduct. It is becoming more generally recognized that both purposes may be combined in one operation. The water is injected into the reservoirs through wells; and the efficiency of the whole process depends, in large measure, on their intake capacities. It is, therefore, worth while to study the behavior of injection wells, to inquire why wells in the same area often have different water-intake capacities, and to learn the reason why intake capacities vary with time in any one well.

When water first is introduced into an underground reservoir through a well, the rate at which the well takes water is a maximum. The intake capacity decreases rapidly during the first few weeks, and then continues to decline more slowly, until finally almost constant quantities of water can be injected into the reservoir per unit time for long periods.

The initial water-intake rate of a well depends on: (1) Effective permeability of the sand; (2) viscosity of the water; (3) thickness of the sand; (4) effective radius of the well; (5) pressure within the reservoir; and (6) applied water pressure. As more and more water is injected into a reservoir, other dependent factors come into the picture. The water fills the pores of the sand near the well; and, as this liquid-saturated region extends, the same pressure applied at the well head forces less and less water into the reservoir. This decline in input rate is caused by the increasing resistance to flow as more and more water enters the reservoir. This so-called fillup factor "7a" will be called the effect of r_e, the pressured, or external radius. As suspended solids or gelatinous materials in the water reduce the effective permeability of the sand at the walls of the well, another factor,' the plugging by foreign matter in the water, is important in reducing the intake rate.

Certain of these factors can be varied at will, whereas others cannot. It is important, therefore, to evaluate each of them as far as possible if the behavior of injection wells is to be understood. During

*Quaker State Oil Refining Corp., Bradford, Pa. †South Penn Oil Co., Bradford, Pa. ‡Prepared as a study sponsored jointly by the Topical Committee on Production Technology and the Subcommittee on Secondary-Recovery Methods.

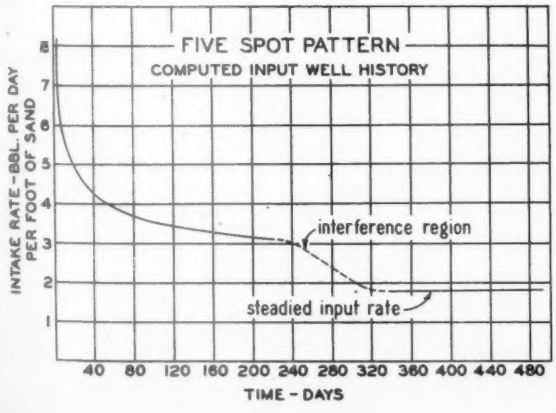


Fig. 1

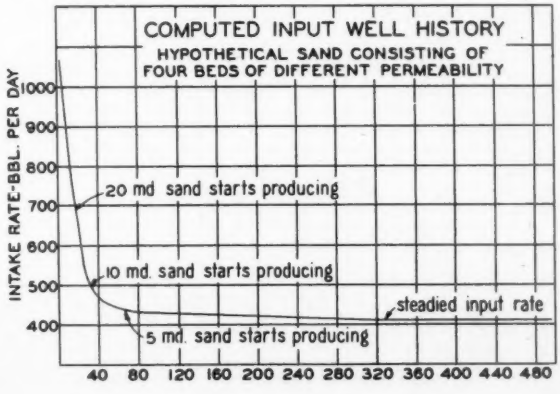


Fig. 2

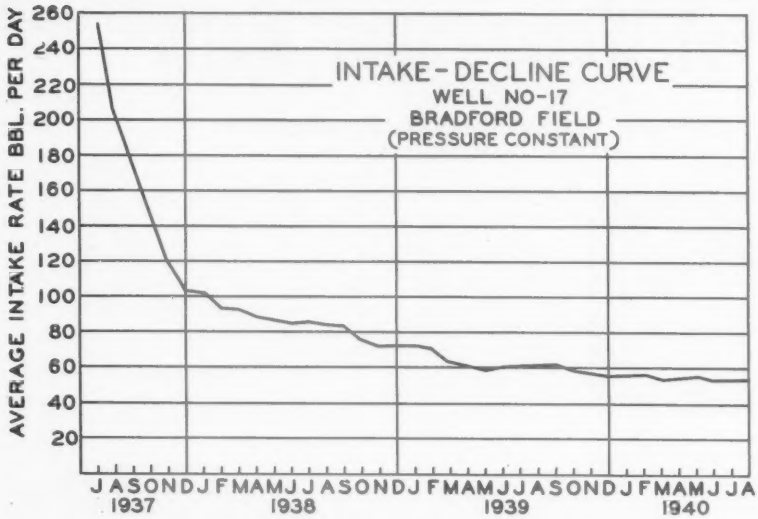


Fig. 3—Intake-decline curve of a well in the Bradford field

drilling it is possible to increase the effective well radius by using a larger bit, or by shooting or acidizing the well. After the well has been completed, it is no longer possible to change the radius.

The effective permeability of the sand can be decreased by plugging, either accidentally by injecting dirty water, or deliberately, if it is desired to decrease the intake capacity of certain strata ("controlled or selective plugging"). The applied water pressure can be raised at will, but must not exceed the safe limit above which rupture of the formation takes place. As a rule, the viscosity of the water, thickness of the sand, pressure within the reservoir, and the effect of the fillup cannot be controlled.

In designing water-injection projects, the controllable factors such as the effective well radius and applied pressures should be fixed at their maximum, or maximum efficient values. After the well has been put in operation, the decline in water-intake rate to a greater or less extent defeats the purpose of the well. The causes of the decline should, therefore, be determined and the controllable causes distinguished from those that cannot be controlled. Factual and observational data that make it possible to distinguish and evaluate these factors are very scarce, nor have standard techniques for their determination been developed. Accordingly, this paper attempts to review the facts that are known, and to suggest new methods of determining certain of the factors.

2. Theory of Water Injection

a. General equation.—Muskat[1] has shown that the relation between the production (or intake) rate of a single well and the characteristics of the fluids, sand, well, reservoir, and pressures can be expressed mathematically by the following equation:

$$Q = \frac{2\pi k h (p_e - p_w)}{\mu \log_e \frac{r_e}{r_w}} \qquad (1)$$

where:

Q = rate of production (or intake), milliliters per second.
k = effective permeability, darcys.
p_e = pressure in reservoir, atmospheres.
p_w = pressure at sand face of well, atmospheres.
h = sand thickness, centimeters.
μ = viscosity of liquid, centipoises.
$\log_e$ = natural logarithm, base e.
r_e = distance from well to point where pressure is p_e, centimeters.
r_w = effective radius of well, centimeters.

The derivation of this equation is based on the fact that the flow of an incompressible fluid through any circle concentric with the well must be constant, and is based upon Darcy's law, which is the law governing the flow of fluids through a porous medium. The equation, therefore, will apply either to a well producing liquids or to one receiving them. It can be applied to the actual field operation of a water-input well with fewer qualifications and uncertainties than to a producing oil well. An intake well receives only water, whereas an oil well may produce a nonhomogeneous mixture of oil, water and gas—which causes variations in the values of some of the factors in the formula. The distance r_e is a rather uncertain dimension in the case of a producing well; but, in the case of an injection well, the average distance to which the pressure has extended outward from the well can be calculated from the porosity of the sand, its fluid content, and the cumulative volume of water injected. As r_e appears as the logarithm in the equation, it is a fairly insensitive function above its low values.

There are numerous uncertainties which make quantitative applications of the flow formula difficult; they do not, however, impair its usefulness in explaining the relative importance of each of the included factors.

b. Effective permeability. — The factor k in the general equation is not the permeability of the extracted and dried sand to air as it is usually measured, but the effective permeability of the sand to water, which is always less (and often much less) than the dry permeability. It varies principally with the water saturation of the sand. In an oil sand the oil saturation seldom becomes less than 15 to 25 per cent. The gas saturation may also remain quite appreciable because of trapped bubbles, and may amount to 5 to 10 per cent or more. In the immediate vicinity of the well, however, the gas saturation will decrease to a low value as water is injected because of the gradual solution of the gas in the water and the compression of the free gas to a small volume. Due to residual oil and gas

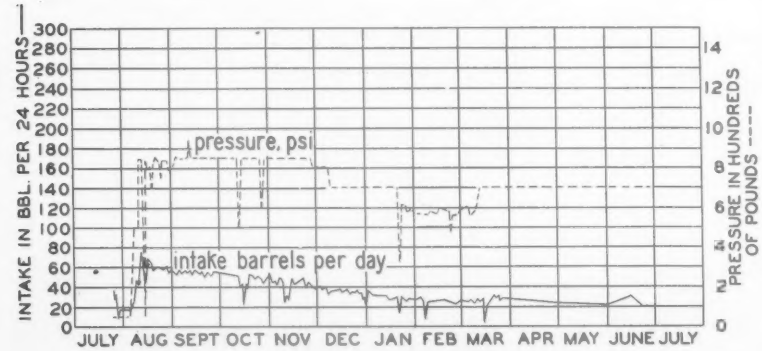
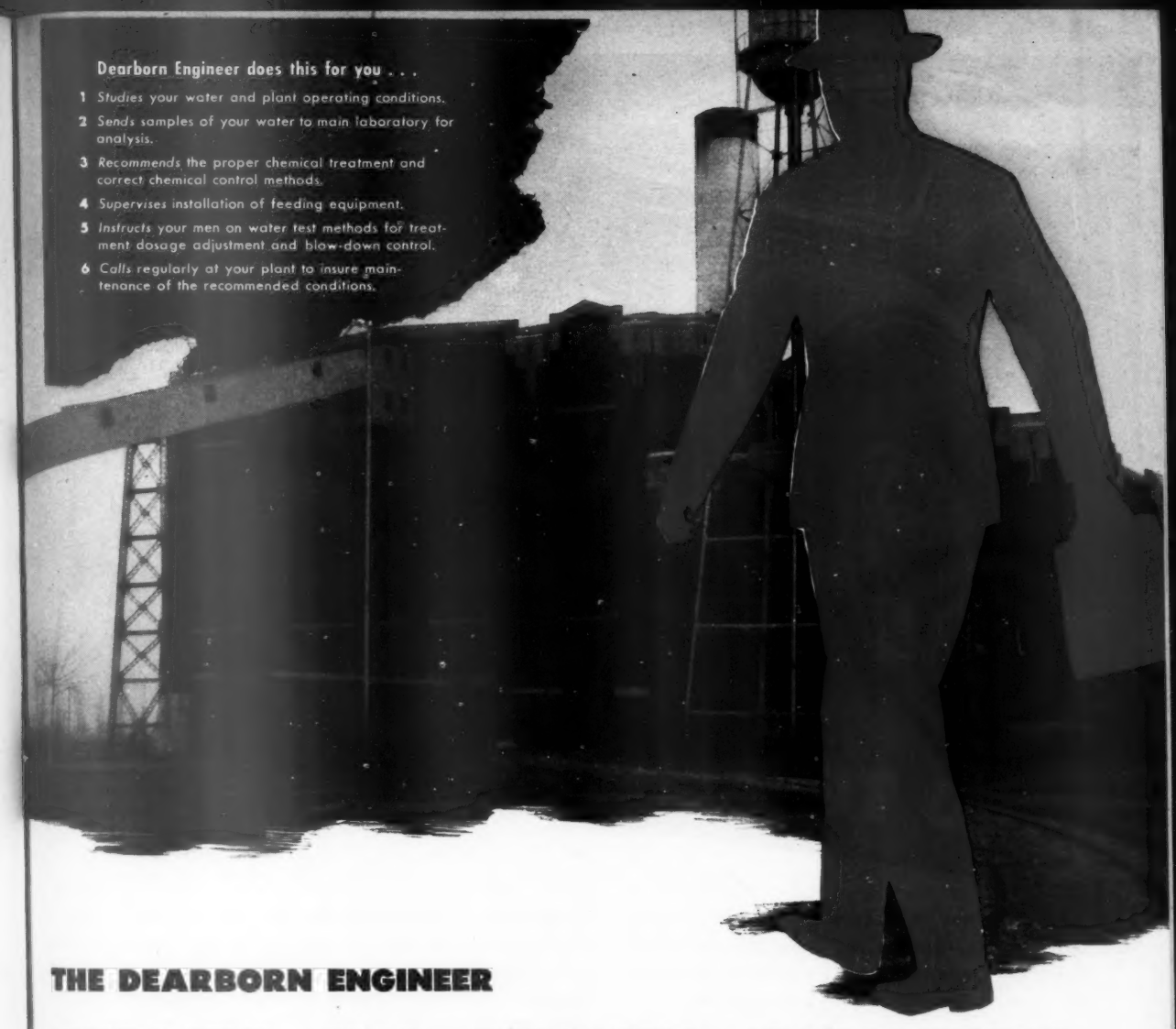


Fig. 4—Input and pressure history of 054-F2, Clintonville, Pa.


Dearborn Engineer does this for you . . .
1 Studies your water and plant operating conditions.
2 Sends samples of your water to main laboratory for analysis.
3 Recommends the proper chemical treatment and correct chemical control methods.
4 Supervises installation of feeding equipment.
5 Instructs your men on water test methods for treatment dosage adjustment and blow-down control.
6 Calls regularly at your plant to insure maintenance of the recommended conditions.

THE DEARBORN ENGINEER

SERVES THE POWER INDUSTRY

The Dearborn Engineer is within calling distance of your plant. When trouble starts in the boiler room, he can be on his way pronto to head it off. He knows local water characteristics and comes fully equipped to make on-the-spot analyses of water samples and plant operating conditions.

Long experience as a water expert enables him to work with your men in installing initial corrective measures to prevent boiler shutdowns due to scale, foaming, and corrosion. His findings are then double-checked by Dearborn home laboratories and there chemical formulas and control methods are established to fit your individual needs and end your boiler water troubles for all time.

Get in touch with the Dearborn Engineer in your district or write to us direct. We'll see that he calls promptly.

DEARBORN CHEMICAL COMPANY, Dept. K, 310 S. Michigan Ave., Chicago 4, Illinois.

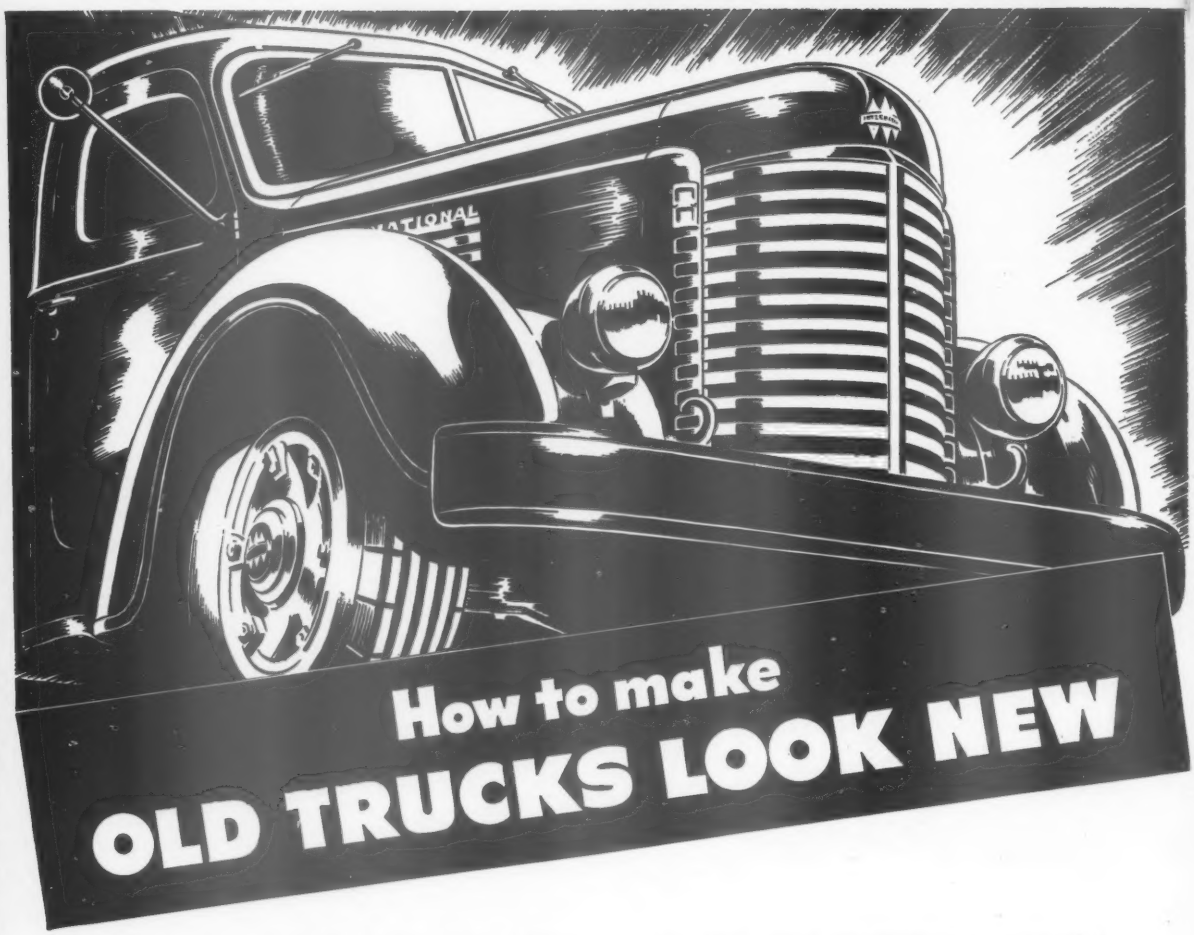
Dearborn

TRADE MARK REGISTERED

THE LEADER FOR OVER 25 YEARS

ENGINEERING SERVICE AND WATER TREATMENT

XUM



How to make OLD TRUCKS LOOK NEW

• Here's a way to make old trucks look new—quick. Drive them to your International Truck Branch or Dealer and say, "I want an Appearance Reconditioning Job done on these fellows."

And you'll get it, because sheet metal and other materials that were out because of the war, are back. You'll get perfect fitting new International fenders, radiator grilles, hood sheets, doors, glass, hardware, headlights, bumpers, bumper guards and seat cushions—just what you want to put your trucks in shape.

Next, paint jobs if the trucks need them—new paint to clean-up-and brighten-up the whole trucks, and cause people to say, "There's one operator who certainly keeps his trucks looking swell."

The cost? Not great. The result? Marvelous.

Act now. Truck production has increased, but it will take many years to meet the demand. Get your trucks "Appearance Reconditioned" by your International Truck Branch or Dealer. Make 'em good advertisements for you while you get additional economical miles from them.

Get These Too When You Get Your Trucks

"APPEARANCE RECONDITIONED"

• Hot Water Heaters and Defrosters • Seat Covers Elston Electric Road Sanders • Saf-T-Step • SOS Fire Guard • Whiz Automotive Chemicals • Spot Lights, Fog Lights and Driving Lights • Clearance Lights, Flags, Flares, Directional Signals and other Safety Devices.

All available from your International Truck Branch or Dealer

INTERNATIONAL HARVESTER COMPANY
180 North Michigan Avenue Chicago 1, Illinois

INTERNATIONAL

INTERNATIONAL Trucks

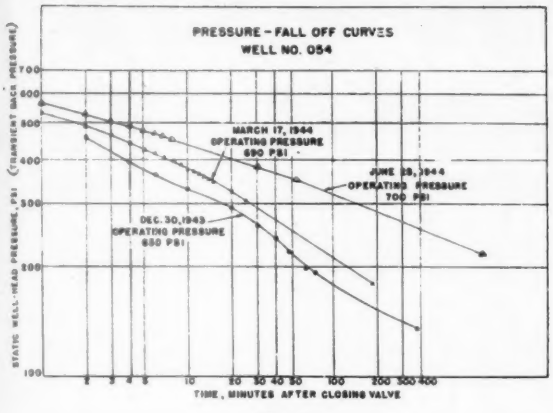


Fig. 5

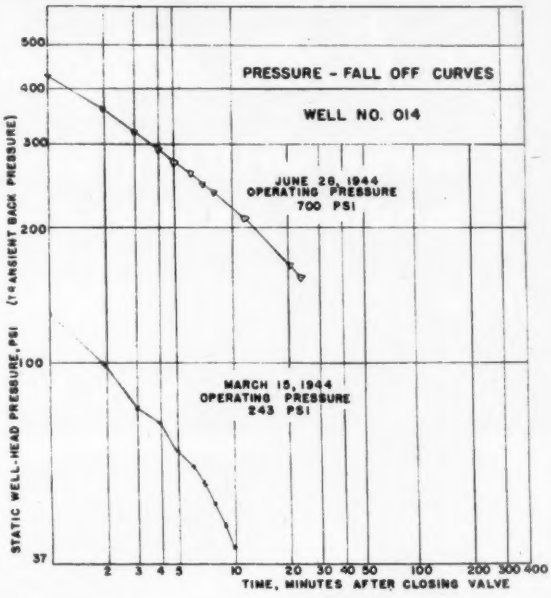


Fig. 6

the water saturation in a flooded-out sand can seldom exceed 85 per cent, and may be as low as 70 per cent. According to laboratory work[2] on clean sands, the permeability of water ranges from 30 to 60 per cent of the dry permeability as the water saturation varies from 70 to 85 per cent. Tests on virgin and artificially oil-saturated cores show that the effective permeability of a sand to water is often less than one-tenth of the dry permeability. A determination of the effective permeability of the unextracted sample to water would be a far more useful test to run on cores of injection wells than the usual permeability tests.

The effective permeability of the sand adjacent to the well can be, and probably often is, materially decreased by mudding off during drilling and cleaning out.

The permeability of the sand to oil affects the intake rate when oil is being banked and driven ahead of the water. Its effect is not large when the "bank" is a considerable distance from the well. When the values are known, the equation may be considered a two-fluid system.[3] When the sand is altogether watered out, the intake rate should increase slightly because of the removal of oil from the system.

c. Viscosity.—The viscosity of the injected water can easily be measured; and, except in the case of strong salt water or in high-temperature formations, is usually not far from one centipoise. When oil is being moved in the sand, the equation for the two-fluid system may be used but, in general, the correction for the viscosity of the oil is not large.

d. Sand thickness.—The effective sand thickness is a characteristic of the geology, which cannot be changed. The thickness of the sand body can be determined by coring the wells; and, when combined with permeability determinations, a weighted average permeability of the total net sand can be calculated. In other words, the effective permeability, k, times the net thickness of sand, h, may be considered "foot-millidarcy capacity" of the sand.

e. Pressure.—The pressure p_w at the face of the sand can be determined from the well-head pressure and the depth of the well and the density of the water. In general, it is equal to the well-head pressure plus 0.434 times the depth of the well. The reservoir pressure p_e can usually be determined from the height of the column of formation liquid in the well before the water is turned in and from its density. The reservoir pressure is sometimes surprisingly high in many oil sands that are virtually depleted of their recoverable oil by ordinary producing methods.

f. Well radius. — The effective radius of the well is very difficult to determine in the case of a well that has been shot. Comparison of intake rates of shot and unshot wells in the Bradford field[4] indicates that the cracks resulting from the shot have the same effect as increasing the well radius to several feet, although the material removed from the well shows that the actual radius has been increased only slightly. A heavy shot will increase the intake rate four or more times.

g. Pressured radius. — The pressured radius r_e can be estimated, at least roughly, from the amount of water injected and the available pore space. The latter will be total pore volume less that occupied by interstitial water and oil.

3. The Filling of the Reservoir

The fundamental equation for the rate of water injection has been given as Equation 1. As more and more water is injected, the "pressured radius" r_e in the equation increases and, therefore, Q, the injec-

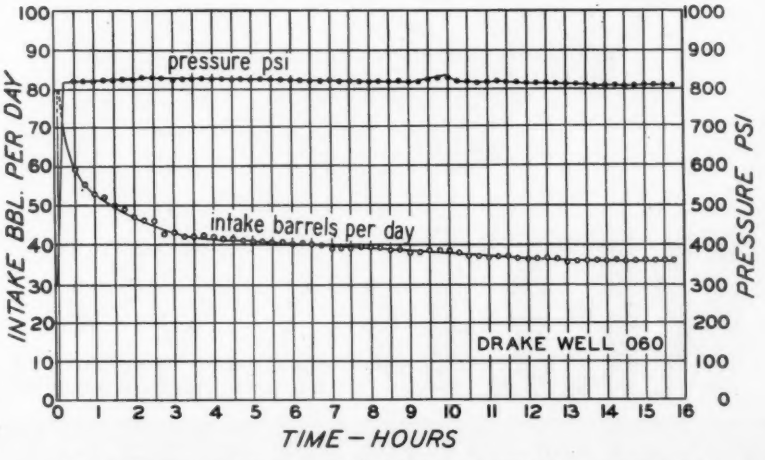


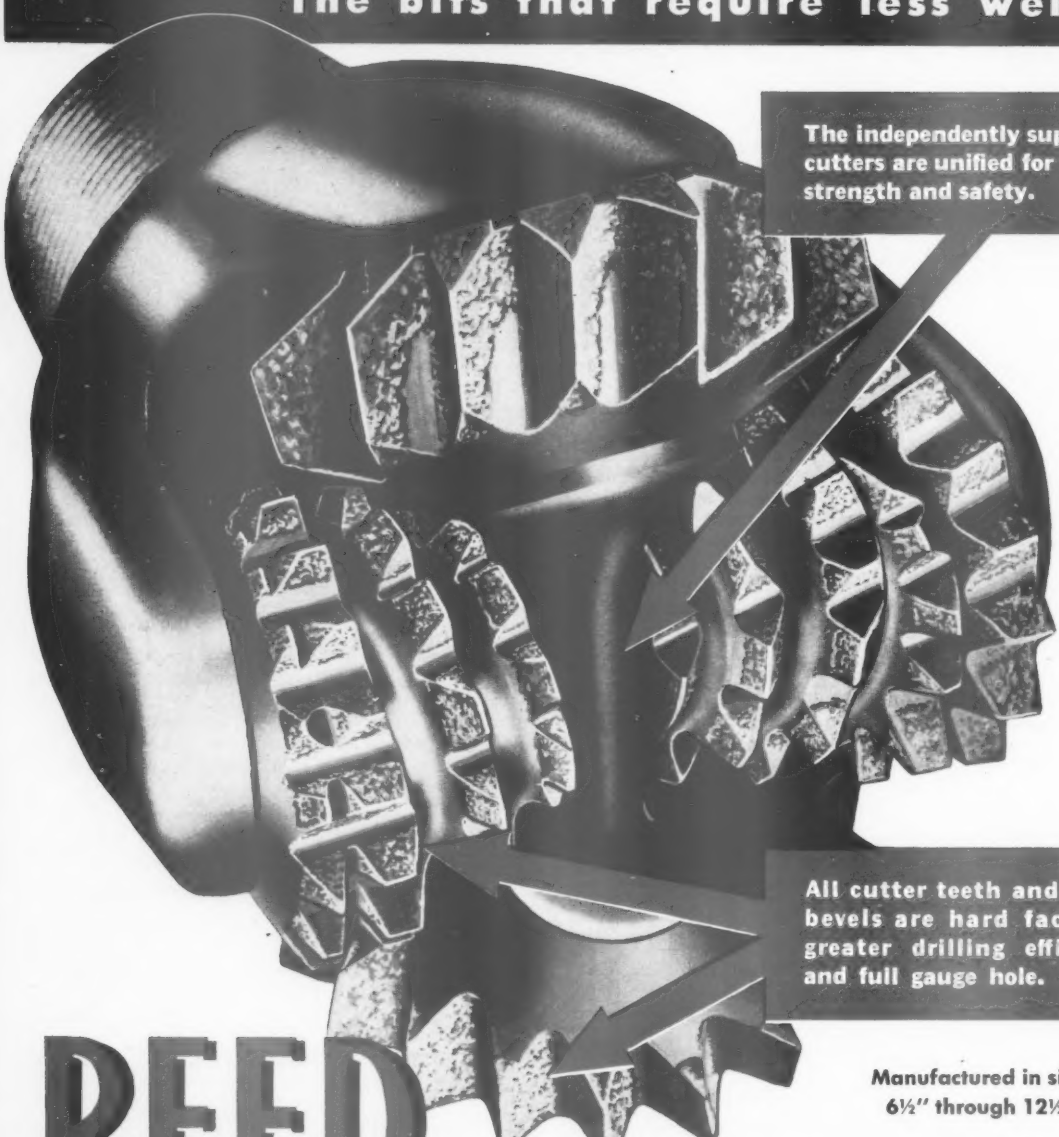
Fig. 7—Decrease in intake rate with time of well, Drake 060 (Bradford, Pa.)

FOR *faster, straighter, full-gauge hole*

when drilling broken formations in the medium hard and abrasive limestone strata

use REED **2HM** ROCK BITS

The bits that require less weight



The independently supported cutters are unified for greater strength and safety.

All cutter teeth and gauge bevels are hard faced for greater drilling efficiency and full gauge hole.

Manufactured in sizes 6½" through 12½"

REED ROLLER BIT COMPANY

P. O. BOX 2119 • HOUSTON, TEXAS

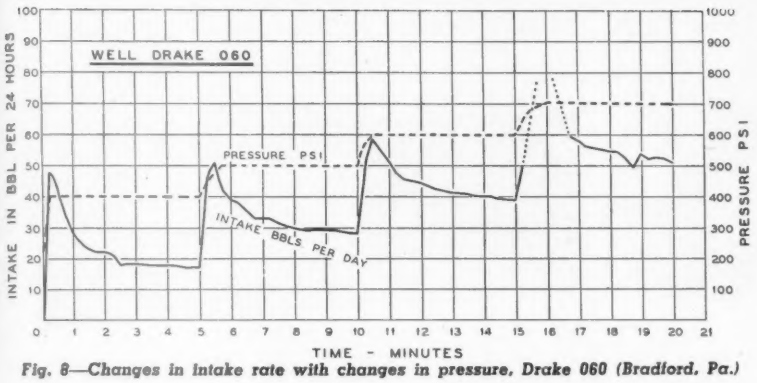


Fig. 8—Changes in intake rate with changes in pressure, Drake 060 (Bradford, Pa.)

tion rate, must decrease with time.

The pressured radius, r_e, depends on the cumulative volume of water injected, and the space available, as follows:

$$V = \pi f h r_e^2 \qquad (2)$$

where:

V = cumulative water injected, milliliters.

f = fractional part of the rock available for the water.

In general, f will be the porosity of the rock, multiplied by the gas saturation. The oil may or may not be moved by the advancing water. If no oil is moved, the water fills the gas space. If oil is moved ahead of the water bank, the liquids of injected water to fill the reservoir with liquids (oil and water) to a given distance r_e will still be the volume originally filled with gas.

If a large percentage of oil is being removed, Equation 1 is not strictly true, and the more exact expression is:

$$Q = \frac{2\pi h (p_w - p_e)}{\frac{\mu_w}{k_w}\log_e\frac{R_w}{r_w} + \frac{\mu_o}{k_o}\log_e\frac{r_e}{R_w}} \qquad (3)$$

where:

μ_w = viscosity of the water, centipoises.

μ_o = viscosity of the oil, centipoises.

k_w = effective permeability of the sand to water, darcys.

k_o = effective permeability of the sand to oil, darcys.

R_w = radius of encroached water, centimeters.

The other symbols are as defined under Equation 1.

As a rule, the width of the oil bank is small in comparison to the radius of the encroached water, so that no very large error will be introduced by considering the simpler case.

From Equations 1 and 2 the change in cumulative volume of water injected with time can be calculated. It is given by:

$$\frac{V}{\pi h f}\left(\log_e\frac{V}{\pi h f r_w^2} - 1\right) + r_w^2 = \frac{4 k \Delta p t}{\mu f} \qquad (4)$$

The change in intake rate with time is given by:

$$\frac{4 k \Delta p t}{\mu f r_w^2} = 1 + \left(\frac{4\pi k h \Delta p}{\mu Q} - 1\right) e^{\frac{4\pi k h \Delta p}{\mu Q}} \qquad (5)$$

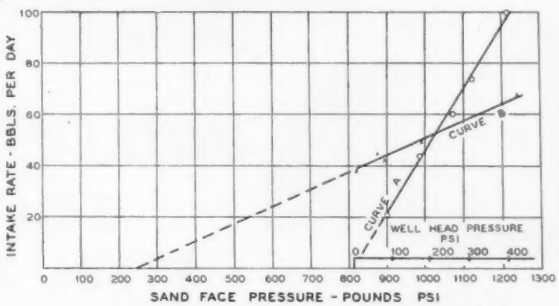
where:

$$\Delta p = p_w - p_e$$

In customary oil-field units, this is:

$$\frac{0.0253 k \Delta p t}{\mu f r_w^2} = 1 + \left(\frac{0.0142 k h \Delta p}{\mu Q} - 1\right) 10^{\frac{0.00617 k h \Delta p}{\mu Q}} \qquad (6)$$

In Equation 6 V is in barrels, h and r_w are in feet, p is in pounds per square inch, k is in millidarcys, and t is in days. It should be emphasized that the permeability k is the effective permeability of the natural sand to water. This is a small fraction of the permeability of the extracted and dried sample to air.



Curve A, pressure increased in 10-minute intervals.
Curve B, pressure increased in 24-hour intervals.

Fig. 10—Pressure-input tests of Well 028 (Bradford, Pa.)

The change in intake rate with time, as given in the foregoing formulas, is plotted in Fig. 1 for a five-spot pattern of 300-ft. spacing be-

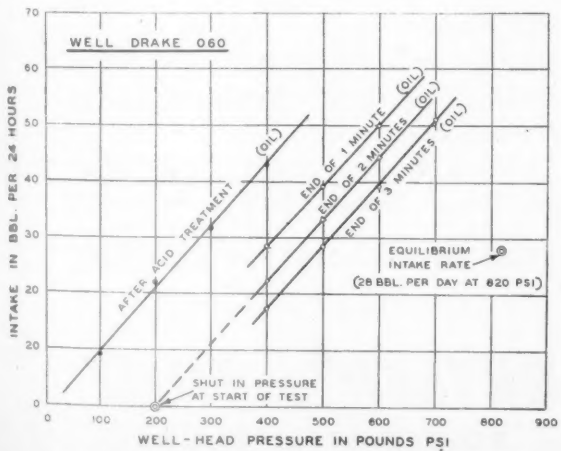

WELL DRAKE 060
AFTER ACID TREATMENT (OIL)
END OF 1 MINUTE (OIL)
END OF 2 MINUTES (OIL)
END OF 3 MINUTES (OIL)
EQUILIBRIUM INTAKE RATE
(28 BBL. PER DAY AT 820 PSI)
SHUT IN PRESSURE AT START OF TEST
INTAKE IN BBL PER 24 HOURS
WELL-HEAD PRESSURE IN POUNDS PSI

Fig. 9—Pressure-input tests of Drake 060 (Bradford, Pa.)

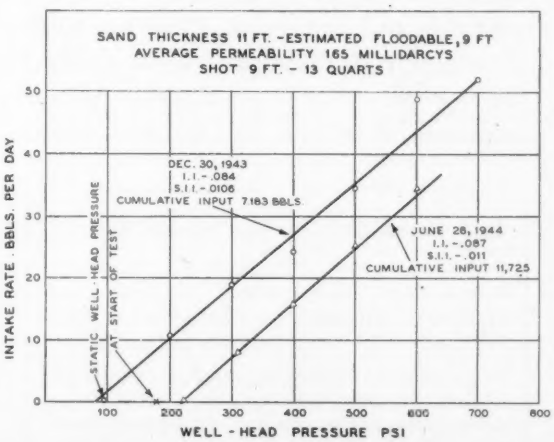
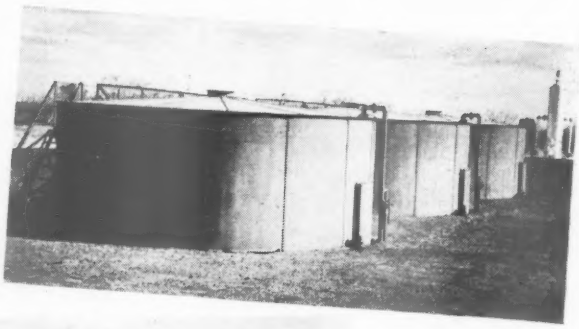

SAND THICKNESS 11 FT. - ESTIMATED FLOODABLE, 9 FT
AVERAGE PERMEABILITY 165 MILLIDARCYS
SHOT 9 FT. - 13 QUARTS
DEC. 30, 1943
I.I. - .084
S.I.I. - 0106
CUMULATIVE INPUT 7,183 BBLS.
JUNE 28, 1944
I.I. - .087
S.I.I. - .011
CUMULATIVE INPUT 11,725
STATIC WELL-HEAD PRESSURE AT START OF TEST
INTAKE RATE, BBLS. PER DAY
WELL - HEAD PRESSURE PSI

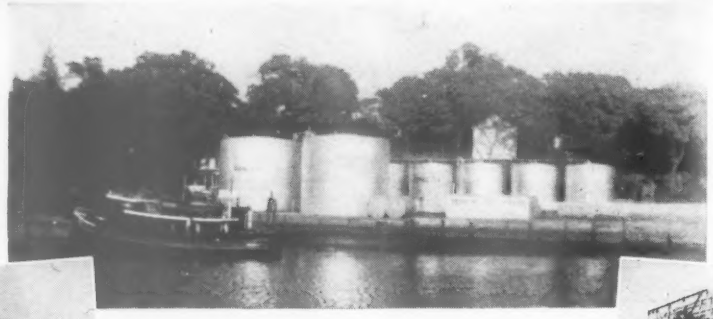
Fig. 11—Pressure-input tests of Well 054 (Clintonville, Pa.)



Above — Seven Butler 1,000 bbl. Tanks for Gasoline Storage.

Above—Battery of Butler 500 bbl. Low Oil Field Tanks.

At right — Butler-Built Salt Water Terminal for Gasoline and Oil—Total Capacity 8,000 bbl.



Below — Butler 10,000 bbl. Low Tank.

Below — 500 bbl. Butler High Tanks, Stairs and Walkways.

BUTLER BUILT
Reg. U.S. Pat. Off.

BOLTED STEEL TANKS

Structurally Strong . . . Easy to Erect . . . Versatile in Use

Bolted Steel Storage Tanks, Walkways and Stairs of every A.P.I. size are fabricated by Butler for the oil fields. Their fire-safety, structural strength and economy make Butler Bolted Steel Tanks ideal for all types of petroleum storage at oil fields and refineries. They are compact to ship in their plate form, packed for ease of assembly on the site. When required, they can be quickly taken down, moved and re-erected at another location, with virtual full salvage.

Butler engineering service is available to assist you in planning your petroleum storage facilities by selecting the best and most economical type of Bolted Steel Tank.

For information, during A. P. I. Convention, call Butler Headquarters at Stevens Hotel.

Address all inquiries to: 7464 East 13th Street, Kansas City 3, Missouri.

BUTLER MANUFACTURING COMPANY
Kansas City 3, Missouri
Sales Offices in Principal Cities

Call These Experts for Expert Service

AMERICAN PIPE AND SUPPLY COMPANY
Denver, Colo. Casper, Wyo. Cut Bank, Mont.

HARRY G. MILLER WRAY RICHARDS
El Dorado, Ark. Alice, Longview and Luling, Tex.

CRAWFORD TANK AND SUPPLY COMPANY
Dallas, Houston, Odessa, Corpus Christi, Tex.
Lake Charles and Houma, La. Great Bend, Kans.
Tulsa, Okla. Hobbs, N.M. Laurel and Natchez, Miss.

BUTLER BUILT
Reg. U.S. Pat. Off.
BOLTED STEEL TANKS
STAIRWAYS & WALKWAYS

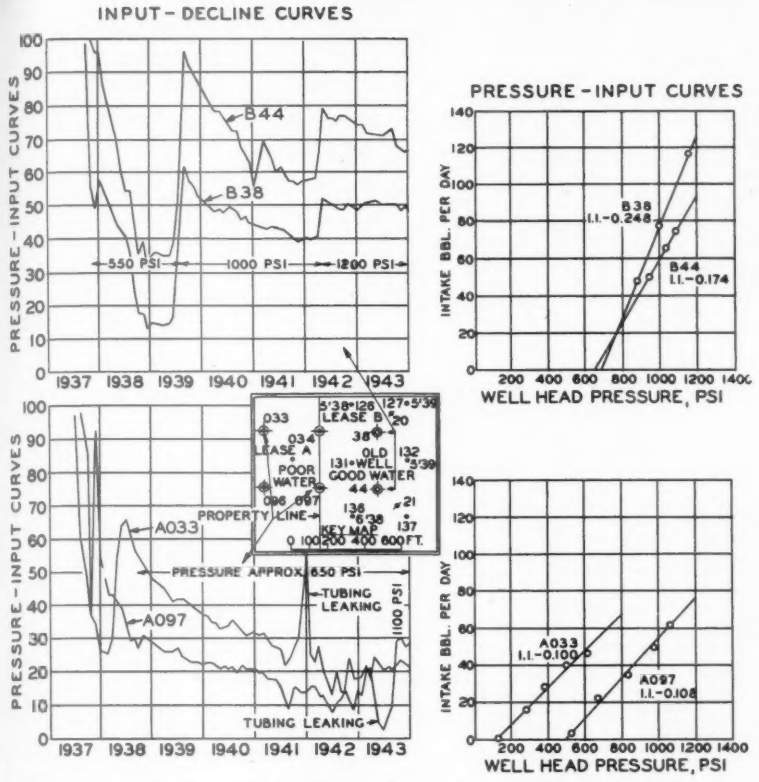


Fig. 12—Comparison of input-decline and pressure-input curves of four wells on adjacent leases "A" and "B," (Bradford, Pa.)

tween water-input wells. The following quantities are assumed:

k = 1 md. effective permeability to water.
Δp = 1,000 psi. difference between sand face and reservoir pressure.
μ = 1 centipoise viscosity.
f = 0.07 of bulk volume space for the water to fill in order to reach 100 per cent liquid saturation.
r_w = 15-ft. effective radius. (This is not the actual radius, but the estimated effective radius produced by the cracking effect of the shot.)
h = 1-ft. sand thickness

Inasmuch as Equations 4 and 5 are for a single well (radial flow), they are no longer valid when the encroaching liquid bank meets the banks from neighboring wells. When this occurs, interference takes place; and, as the advancing liquid is forced to converge toward the producing wells, the intake rate is reduced—finally becoming stabilized at the steady conductivity of the pattern. For the five-spot this is given as:

$$Q = \frac{\pi k h \Delta p}{\mu \left(\log_e \frac{D}{r_w} - 0.6190\right)} \quad (7)$$

Or, in customary units:

$$Q = \frac{0.00154 k h \Delta p}{\mu \left(\log_{10} \frac{W}{r_w} - 0.420\right)} \quad (8)$$

where:

Δp = difference in sand-face pressure between input and producing wells, atmospheres.
D = distance between input and producing wells, centimeters.
W = distance between like wells, feet.

It may be assumed that the average intake rate during the time between interference and the complete filling of the pattern is the mean of the rate just prior to interference, and the steady rate of the pattern. The time required to reach the steady rate can then be computed, using the additional volume of water which must be injected between interference and fillup; and the curve can be interpolated, as shown by the dashed line in Fig. 1.

The effect of the interference is shown as a shoulder on the curve. Such shoulders have been noted in some actual input-decline curves; but, as a rule, they are eliminated by the fact that sand bodies consist of numerous layers of varying permeability. This is illustrated in Fig. 2, which is the calculated input-decline curve of a hypothetical well, with the following conditions: Five-spot pattern, 300-ft. spacing between water wells, 15-ft. effective well radius, 1,000-psi. pressure differential, 1 centipoise viscosity of water at formation temperature, and 0.07 fraction of total sand volume to be filled by the injected water. The sand consists of four beds, as follows:

Thickness (ft.)	Effective permeability to water (millidarcys)
10	1
5	5
10	10
5	20

The time when complete fillup takes place in each of the beds is shown by arrows. The curve of Fig. 2 shows the sum of the intake rate of each of the four beds at any particular time computed from Fig. 1, which is based on Equations 6 and 8.

The input-decline curve of an actual well in the Bradford field is shown in Fig. 3.

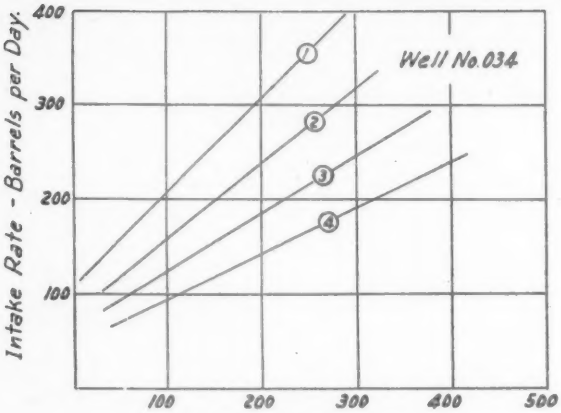
The input-decline curve of a well (054) in the Clintonville field (in Pennsylvania) is shown in Fig. 4. This curve, like that of most wells, is somewhat complicated by variations in pressure. The well is 980 ft. deep, the sand has a thickness of 11 ft., of which 9 ft. were shot. The average permeability is 165 md.

Figs. 12, 21, 22, and 23 are other examples of actual input-decline curves.

4. Injectivity Index

a. General.—The preceding chapter discusses the decline in intake rate as the reservoir fills up, and the effect of the different patterns on the subsequent steady intake rate. As a matter of fact, after the reservoir has been completely (or almost completely) saturated with liquid, the water-intake rate would be expected to increase slightly as the effective permeability of the sand to water increases with the removal of oil. Unless, however, the quality of the injected water is exceptionally good, the intake rate does not even remain constant, but continues to decline because of plugging of the sand face at the input wells by suspended matter or other impurities in the water. It is important to be able to tell, as the intake rate declines in the early stages of injection, whether the decline is due to plugging of the sand and, therefore, remedial, or to the fillup of the reservoir and, therefore, irremedial. What is required, therefore, is a method of determining the intake capacity of the well itself without regard to the conductivity of the whole system surrounding it. Such tests could be made periodically on certain selected

XUM



Curve 1: Before treatment
Curve 2: After first treatment
Curve 3: After second treatment
Curve 4: After third treatment

Fig. 13—Pressure-input tests of well 034 (Bradford, Pa.), showing changes in injectivity index after successive plugging treatments with wax emulsion

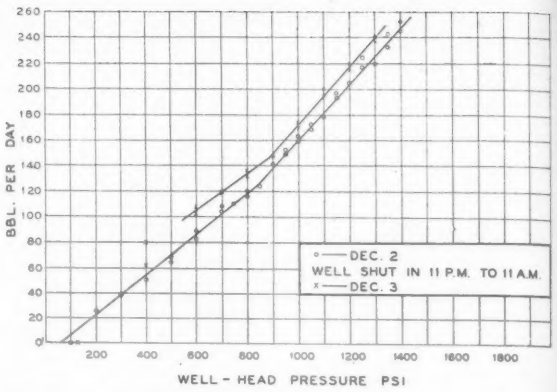


Fig. 15—Pressure-input curve of well in Clintonville field showing break in injectivity index

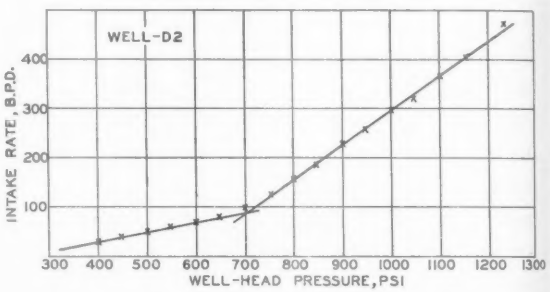


Fig. 16—Pressure-input test of Well D-2 (Bradford, Pa.)

wells scattered over a flood, and a close check on the efficiency of the input wells could be maintained.

It is believed that an entirely practical method of determining the efficiency of an input well is the determination of the localized injectivity index of the well. Injectivity index is the reverse of productivity index,[6] a concept that has proved of value in the study of the efficiency of producing wells.

Injectivity index is defined[7] as "the number of barrels per day of gross liquid injected into a well per pound per square inch pressure differential between mean injection pressure and mean formation pressure referred to a specific subsurface datum, usually the mean formation depth." In order to be most useful, in studying the behavior of individual input wells this concept should be restricted to define the conductivity of the individual well and not the general conductivity of the whole system; i.e., it should not be affected by the whole area of sand surrounding the well and the productivity indices of the adjacent producing wells. It should be the determination of the conductivity of a cylinder of sand surrounding the well, in which cylinder the majority of the pressure drop takes place, and whose inside wall is the sand face—which is apt to become clogged by impurities in the injected water. This restricted index will be called the "localized injectivity index."

Before discussing injectivity index, and methods for its determination further, it is necessary to explain certain transient phenomena that take place when the intake rate of an injection well is changed.

b. Transient back pressure.—Theoretically, the flow of water from a well into the surrounding formation will continue until the intensity of the sand-face pressure is reduced to that of the reservoir pressure. In actual practice, if the pressure on an input well is reduced suddenly to atmospheric pressure at the surface, the well backflows vigorously for a few minutes and may continue to backflow for many hours. It is thus apparent that, when flow into the well stops, a pressure remains in the vicinity of an active input well which is substantially higher than the average reservoir pressure. This pressure will be called the transient back pressure, because it is a transient phenomenon. Its value is determined by shutting in a well and noting the pressure when water has ceased entering the well. It is found that the transient back pressure changes with time. If a well is operating at a constant well-head pressure and is sud-

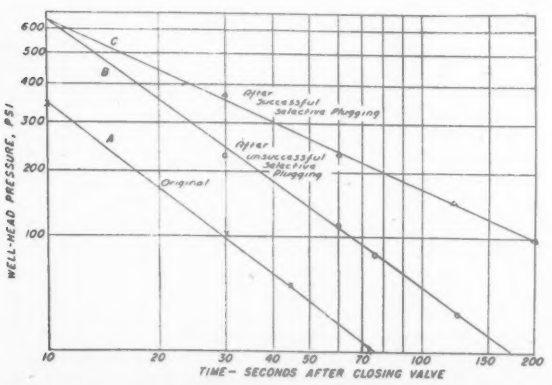


Fig. 14—Pressure fall-off curves after plugging with wax distillate and later with chemicals (Bradford, Pa.)

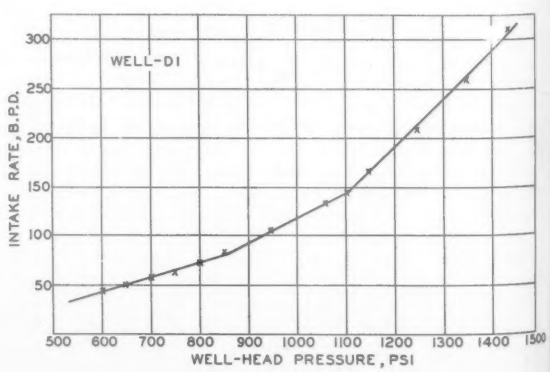
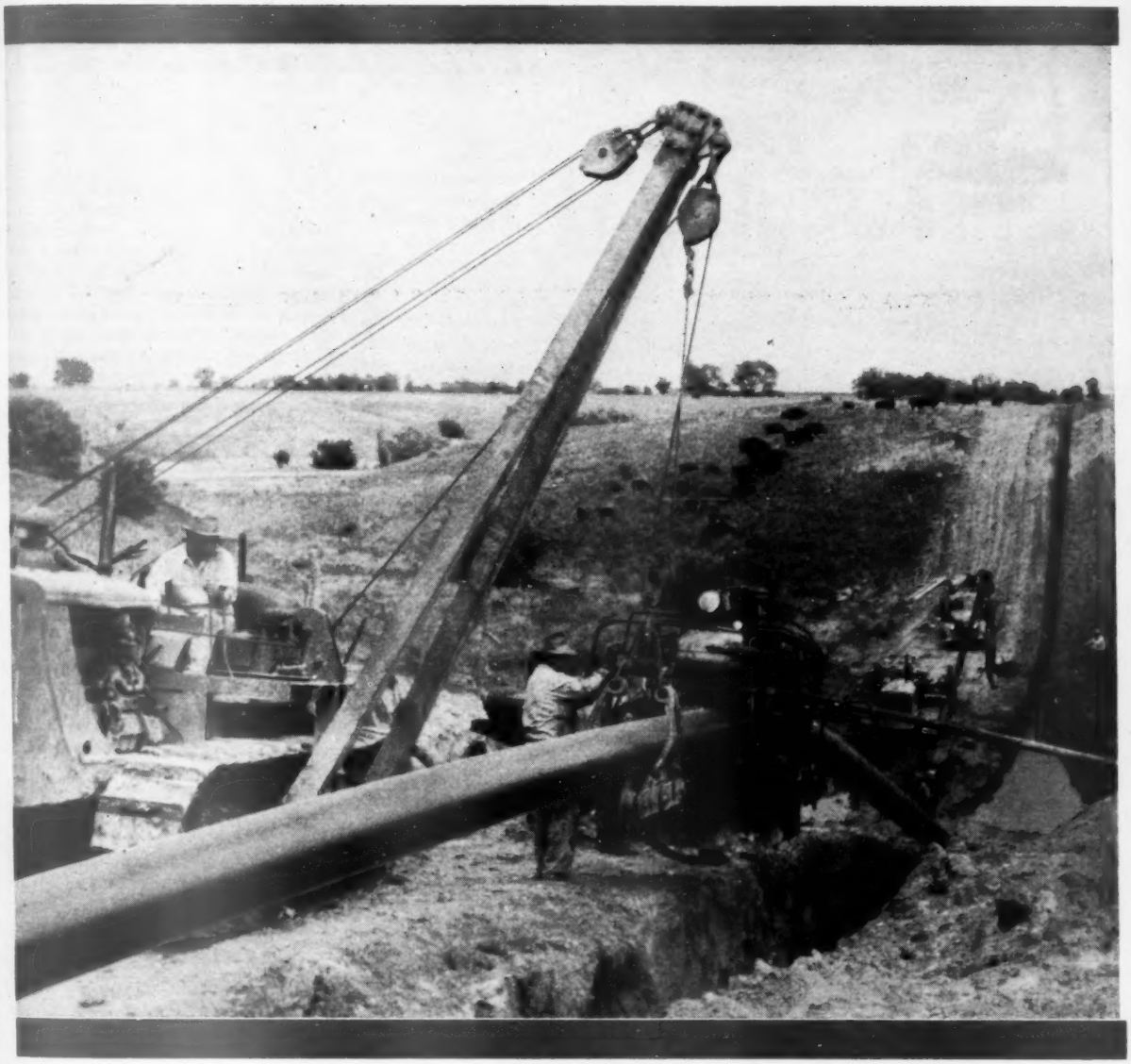


Fig. 17—Pressure-input test of Well D-1 (Bradford, Pa.)



During the past four years, H. C. PRICE CO. has continuously used its personnel, equipment and experience on diversified war projects directed toward one goal only—Final Victory. With the successful termination of the war, our entire organization is again concentrated on the business in which we have had years of experience—PIPE LINE CONSTRUCTION.

QUALITY • EFFICIENCY • RESPONSIBILITY

H.C. PRICE CO.

BARTLESVILLE, OKLA.

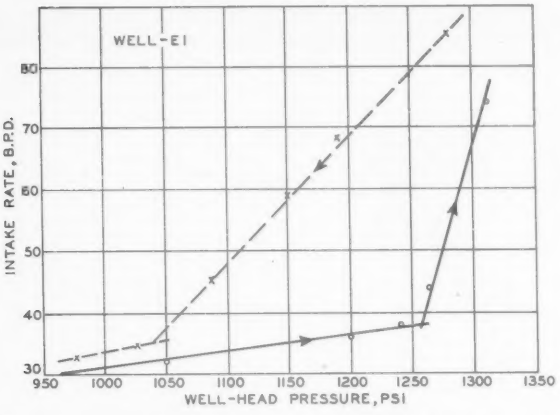


Fig. 18—Pressure-input test of Well E-1 (Bradford, Pa.). Note different injectivity index on lowering pressure

denly shut in, the shut-in pressure falls—rapidly at first and then more slowly — hours, or even days, elapsing before the pressure has declined to zero at the well head. If the pressure readings are plotted against time, the "pressure falloff" curve generally approximates a straight line on double logarithmic paper, which is evidence of an exponential relation. For any particular well the slope of the curve is the same, regardless of the previous operating pressure, but it flattens slowly during the fillup period as the cumulative quantity of water injected increases.

Figs. 5 and 6 are examples of pressure-falloff curves taken at different times on two wells. Well 054 (Fig. 5) had 9 ft. of sand of average permeability of 165 md. which was shot with 13 qt. of nitroglycerin. On December 30, the well had taken 7,183 bbl. of water; on March 17, it had taken 9,196 bbl.; and on June 28, it had taken 11,725 bbl. The latter amount was sufficient to produce interference with the water from the neighboring input wells. The gradual flattening of the curves is noticeable. Fig. 6 shows the falloff curves of another well approximately similar in sand characteristics in the same flood. This curve is abnormally steep, and there is other evidence to indicate that a thief sand is present in which the back pressure falls more rapidly than in the pay sand proper.

The transient back pressures are, as yet, not fully understood, but the following tentative explanation is suggested by the authors. Water enters a well because the pressure is greater in the well than in the reservoir, and continues to flow through the sand by reason of a pressure gradient established therein. This gradient determines, for a particular well, the rate of flow that will take place at any given pressure. It is defined by Muskat's equations (greatest near the well), and decreases with distance to the pressured radius, beyond which it is zero. Muskat's equations are based on the assumption that water is incompressible, which is very nearly true. However, the compressibility of water certainly accounts for some of the back pressure, and a little gas may be present even in a watered-out sand. Volume of free gas in the reservoir is difficult to estimate, but even a small amount (comprising a saturation of less than 1 per cent) would prevent the system from behaving as if it were filled with an incompressible fluid. Speculation indicates that the gas saturation is probably minimum close to the hole where the water is moving most rapidly, and has the best chance to dissolve the gas. Near the well, the pressures are maximum, and the gas is compressed to its smallest volume. The presence of a small quantity of free gas in the sand does not invalidate the definition of the pressure gradient by the equations (except for a probably negligible change in effective permeability to water). Comparatively small quantities of free gas in the sand, however, will explain the transient back pressure. When the input well is shut in, the pressures in the sand start to drop immediately—permitting the gas to expand; and further decrease in pressure is possible only to the extent that the water front continues to advance—making space available into which the gas can expand. Thus the pressure gradient in the sand does not disappear immediately when the water is shut off, as it would if the system were filled with a totally incompressible fluid; but it is maintained by the expanding gas bubbles. As the water front advances, the gradient becomes less and less steep, the rate of movement of the water becomes progressively slower, and the transient back pressure declines more and more slowly. The elasticity of the formation and the small but measurable compressibility of the liquids have an effect similar to that of the compressibility of the gas, and doubtless also contribute to the phenomenon.

When a well is taking water at a steady rate, a sudden increase in pressure will cause an increase in intake rate. This effect is illustrated in Fig. 7 which shows the decrease of intake rate with time of a well in the Bradford field. The well was shut in for about 12 hours, at the end of which time it had a transient back pressure of 300 psi. at the well head. Full line pressure of 820 psi. was gradually applied over a period of 15 minutes. The intake rate during the first half hour was too high to read on the recording orifice meter used in the experiment. It then declined in a manner similar to that described as characteristic of a new well. The decline in intake rate as increasing volumes of water are injected is caused by the increase of the radius around the well (r_e) through which the pressure gradient has become established. The enlargement of the radius results in a continually decreasing series of pressure gradients. As more and more water is injected, it has a smaller effect on increasing the radius (which varies as the square root of the cumulative fillup volume); and, as the radius increases, it has a smaller effect on the intake rate (which varies inversely as the logarithm of the radius). The same effect takes place when the well pressure is suddenly lowered. A sudden drop in pressure will cause a sudden drop in flow, in some cases to zero or even negative (backflow), which gradually increases as the effective transient back pressure dissipates, until it attains a new equilibrium rate.

c. Determination of localized injectivity index.—It is believed that the best way to determine the localized injectivity index of an injection well is as follows:

The well is shut in tightly until the transient back pressure is falling very slowly. It may then be presumed that there is little or no flow of fluids in the sand in the vicinity of the well, and the pressure gradient which existed about the well when it was active has become flat for a considerable distance from the well. In other words, the pressures in the sand near the well have become equalized; this waiting period takes several hours.

The valve is now opened, and the pressure is maintained as steady as possible for a short period of time, say 5 minutes. The volume injected during the period is then noted or, better, the instantaneous intake rate at the end of the period is recorded. The pressure is then raised in equal increments, say 100 psi., and the intake rates at the ends of equal time periods are measured. Sufficient readings should be taken to establish a relation between the intake rate in barrels per day and the pressure in pounds per square inch.

The curve of intake rate plotted against pressure is found to be a straight line up to pressures slight-

(Continued on page 249)

BOVAIRD has the "OK" from OKLAHOMA OPERATORS!

Meeting the growing needs of the Mid-Continent area since the turn of the century with stores and manufacturing facilities in nearby Kansas as early as 1903, Bovaird has served Oklahoma operators since the first wells were drilled in the Sooner state.

Bovaird has a background and experience which admirably equip its organization to intelligently and economically serve the needs of the producing, pipeline and refining industries.

Supplementing the facilities and services of our general offices in Tulsa, Bovaird maintains a district office at Oklahoma City and three properly staffed and adequately stocked stores in Oklahoma.

Oklahoma District Manager, Charley Meyers, Oklahoma City

Oklahoma City Store, Wm. F. Robertson, Manager

Sapulpa Store, Ben Hubbard, Manager

Seminole Store, "Stape" Stapleton, Manager

SUPPLY BOVAIRD COMPANY

OFFICES AND STORES

ILLINOIS—Benton, Grayville, Salem
KANSAS—Chase, McPherson, Pratt, Russell, Wichita
OKLAHOMA—Oklahoma City, Sapulpa, Seminole
TEXAS—Borger, Pampa

"Buy From Bovaird"

THE BOVAIRD SUPPLY CO.

GENERAL OFFICES: TULSA, OKLAHOMA

XUM

WHAT TO LOOK FOR IN VALVES

Valves for oil and gas industry service must have a generous margin of strength at rated pressures. And they should open and close promptly, easily, positively. Kennedy Valves have all these vital advantages, along with other important features. For example—precision machine finish throughout; large diameter handwheels and stems, simple, sturdy disc designs, deep, accessible stuffing boxes easy to inspect and repack—and many other refinements in design. For rugged construction and maximum service with a minimum of attention and maintenance expense, specify Kennedy Valves.

THE KENNEDY VALVE MFG. CO., ELMIRA, N. Y.

KENNEDY
VALVES and PIPE FITTINGS

NOR-BRO-LOY

SWAGED NIPPLES

Norris Brothers' metallurgists developed an alloy steel that was just right. In this application, they engineered the steel for the job it must do.

Constant experiment, constant scientific investigation make possible these masterpieces of metallurgy. Infinite care in production results in a uniformly excellent product. Together, these factors have built a reputation for progress in alloy steel development for a specific purpose.

These swaged nipples are made in sizes from ¼-inch to 1½-inch inclusive.

Norris Brothers, INC.
ROBINSON · ILLINOIS

"TWECONNECT"
your Welding Cables . . . . .

CONSERVE expensive cables, machines, current and welding operator's time . . . . . .

USE . . . .

TWECO "STANDARD" and **"Hol-GRIP"** plain and fully insulated Electrode Holders are cool running, well balanced, easy to operate, moderately priced. Size range from 150 to 500 amperes. 1/32 thru ⅜" Electrodes.

TWECO "REDHEAD" Ground Clamps are made in Midget 125 ampere, Jr. 300 and Sr. 500 ampere sizes. Provide a quick, positive and portable ground. Truly an efficiency "stepper-upper".

TWECO "SOL-CON" Cable Connectors and Machine Terminals provide a quick cable detach anywhere in the welding cable circuit or right at the machine. Made in No. 1 and No. 2 sizes for cables from No. 4 thru 4/0.

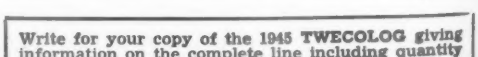
"TWECOLUGS" mechanically and positively "lug" your cables. No solder—No heat—No mess. Made in Hole and Open Side types for from small No. 4 thru 4/0 cables.

TWECO PRODUCTS

Write for your copy of the 1945 **TWECOLOG** giving information on the complete line including quantity price and parts. See your TWECO jobber.

TWECO PRODUCTS COMPANY, WICHITA 1, KANSAS
ENGLISH AT IDA MANUFACTURERS P. O. BOX 600
IN CANADA - G. B. PETERS & CO. OF CANADA, LTD. 1001 BIRKS BLDG., MONTREAL

"CONNECT WITH TWECO"



Interactions Between Interstitial and Injected Water—A Review

*by A. J. W. Headlee**

THE waters considered in this review are those which may be removed from or injected into underground reservoirs, with particular reference to the eastern fields. The chemical reactions are considered that will influence the porosity and permeability to fluids by plugging off or opening up the pores of the rock. The conditions are described under which precipitation or solution of solids takes place.

Composition of Waters

Interstitial waters commonly found in oil reservoirs contain several inorganic salts in solution in amounts varying from a few parts to more than 300,000 p.p.m. These salts are mostly chlorides, sulfates, and bicarbonates of sodium, calcium, magnesium, potassium, strontium, and barium. Other ions that may be present are bromide, iodide, sulfide, phosphate, silicate, carbonate, iron, manganese, aluminum, lithium, and ammonium. It is common practice to report the constituents in terms of ions. Solubilities are usually reported in terms of solid salt; so that, for the purpose of this paper, representative analyses are presented in Table 1, in parts per million of the anhydrous solid salts which may be expected to precipitate out on concentration of the brine or on interaction with other waters.

*Chemist, West Virginia Geological Survey, Morgantown, W. Va.; on leave of absence doing research for the armed forces; present address Johns Hopkins University, Silver Springs, Md. Published by permission of Acting State Geologist R. C. Tucker, Morgantown, W. Va., with publication rights reserved.

TABLE 1—ANALYSES OF WATERS
(In parts per million)

Constituent—	Malden, W. Va.*	Belle, W. Va.†	Webster Springs, W. Va.*
Sodium chloride	65,647	71,363	7,888
Sodium bromide	244	.....	5
Sodium iodide	11	.....	2
Sodium nitrate	Absent	.....	Trace
Sodium arsenite	0.01	.....	.....
Sodium borate	Trace	.....	.....
Potassium chloride	622	695	162
Lithium chloride	110	160	35
Ammonium chloride	86	80	9
Barium chloride	812	274	27
Strontium chloride	220	208	3
Calcium chloride	16,375	24,154	734
Magnesium chloride	5,421	6,295	411
Calcium bicarbonate	290	30	Trace
Ferrous bicarbonate	90	119	2
Manganous bicarbonate	83	97	Trace
Calcium phosphate	0.6	5	.....
Alumina	Trace	.....	0.5
Silica	5	11	8
Magnesium bromide	.....	590	.....

*C. D. Howard, "Barium in Ohio Valley Brines," W. Va. Univ. Agri. Exp. Sta. Bull. 103, Morgantown, W. Va. †Salt Brines of West Virginia 8, 149, W. Va. Geol. Survey.

Precipitates Formed as a Result of Physical Action

Physical changes which may cause precipitation or solution of solids are temperature, pressure, evaporation, and condensation. In order to determine under what conditions precipitation or solution takes place, a solubility table of the more common salts precipitating out of natural waters is given in Table 2. The solubilities are given at 32° and 212° F.

The table shows that chlorides, bromides, iodides, and nitrates will not precipitate until after the total solids reach well over 250,000 p.p.m. Most brines will require considerable concentration due to evaporation of water vapor by large volumes of expanding gas before these salts will precipitate out. Only pro-

A.P.I.

ABSTRACT

An attempt has been made to present quantitative as well as the qualitative aspects of the problem of solids forming in oil and gas-field waters during recovery operations. The purpose is to develop, eventually, sufficient data in one paper so that a balance sheet can be made of the precipitates which may form in any operating system. Many quantitative data remain to be determined.

The more common precipitates which form in recovery systems are carbonates, sulfates, sulfides, sulfur, iron oxide, silicates, and organic residues. Although the quantity of these precipitates which may form is small, it is also true that the quantity necessary to cause serious plugging off of a well is quite small. In fact, a fraction of a pound of fine precipitate may cause a considerable decrease in the permeability of a well. The extent of the plugging-off effects will depend not only on the amount of precipitate formed, but also on its nature. The particles may be too large to enter the pores of the sand. Then, again, they may be small enough to circulate freely through the pores.

A large amount of research work is necessary to complete the picture. It should be possible to obtain sufficient data so that one could predict precipitation before it has a chance to lower the permeability of the sand.

TABLE 2—SOLUBILITY OF COMPOUNDS OCCURRING IN SALT WATER
(Parts per million)

	Chloride		Sulfate		Sulfide	Phosphate		Silicate	Carbonate		Bicarbonate		Bromide	Iodide	Nitrate	Fluoride
Temp. (°F.)	32	212	32	212	32	32	212		32	212	32	212				32
Calcium	330,000	606,000	1,790	1,780	Dec.	23-21	Dec.	....	11[a]	20	(b)	.....	550,000	660,000	600,000	(c)
Sodium	263,000	285,000	50,000	.....	15,000	220,000	....	S.	70,000	300,000	69,000	140,000	440,000	615,000	422,000	.....
Magnesium	315,000	394,000	212,000	425,000	Dec.	205	....	....	(d)	.....	(b)	.....	760,000	500,000	666,000	.....
Potassium	222,000	361,000	85,000	208,000	S.	Sl. S.	....	S.	472,000	.....	184,000	375,000	350,000	361,000	130,000	500,000
Ferric	429,000	843,000	V.S.	.....	Dec.	.....	670	....	.....	.....	.....	.....	S.	.....	V.S.	.....
Ferrous	400,000	520,000	130,000	300,000	9	I.	....	....	I.	.....	(b)	.....	758,000	V.S.	390,000	.....
Barium	220,000	360,000	1.7[e]	.....	Dec.	.....	....	....	22[f]	65	(b)	.....	500,000	630,000	50,000	(g)
Ammonium	227,000	436,000	415,000	.....	V.S.	.....	....	....	(h)	.....	106,000[i]	.....	400,000	V.S.	514,000	V.S.
Lithium	389,000	570,000	260,000	225,000	V.S.	400	....	....	150,000	7,280	55,000	.....	588,000	.....	326,000	.....
Strontium	307,000	500,000	116	104	S.	.....	....	....	11[j]	.....	(b)	.....	467,000	621,000	283,000	(k)
Aluminum	412,000	.....	250,000	471,000	Dec.	I.	....	....	.....	.....	.....	.....	V.S.	.....	V.S.	I.
Manganous	370,000	545,000	347,000	394,000	5	Sl. S.	....	I.	130	.....	(b)	.....	560,000	V.S.	810,000	.....

(a) Calcium carbonate, 12 p.p.m. at 50° F., 13 p.p.m. at 68° F.; solubility, $CaCO_3$ in saturated NaCl solution at 77° F., 26 p.p.m.; (b) See Fig. 1; also gives solubility of carbon dioxide; (c) Calcium fluoride, 37 p.p.m. at 60° F., and 16 p.p.m. at 64° F.; (d) Magnesium carbonate, 106 p.p.m. at 50° F., 218 at 77° F., 176 at 73° F.; $Mg(OH)_2$, 9 p.p.m. at 64° F.; (e) Barium sulfate, 1.9 p.p.m. at 50° F., 2.3 at 68° F., 3.3 at 122° F.; (f) 68° F.; (g) Barium fluoride, 1,630 p.p.m. at 64° F.; (h) Ammonium carbonate, 500,000 p.p.m. at 59° F., and decomposes at 185° F.; (i) Ammonium bicarbonate, 213,000 p.p.m. at 86° F.; (j) Strontium carbonate, 11 p.p.m. at 64° F.; (k) Strontium fluoride, 120 p p.m. at 64° F. Dec.—decomposes. V.S.—very soluble. I.—insoluble. Sl. S.—slightly soluble.

XUM

ducing wells will be influenced by this evaporation. Gas wells are especially susceptible to precipitation by evaporation. This precipitation in gas wells needs more thorough investigation. Due to slight physical changes, the slightly soluble salts given in the table are susceptible to precipitation. Those which will precipitate can be found by comparing the analyses (Table 1) with the solubility (Table 2). Inasmuch as the slightly soluble salts usually are also precipitated out by chemical action, they will be considered under that heading.

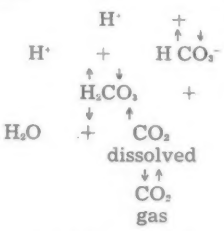
Temperature Effects

The solubility of most salts increases with temperature. Some show only slight increases; whereas a few, including gases, are less soluble at high than at low temperatures. Some salts decompose into less soluble compounds at higher temperatures. Slightly soluble bicarbonates do this because the solubility of the carbon-dioxide gas is less as the temperature rises. Some quantitative relations of this reaction are shown in Fig. 1.

Precipitates Formed by Chemical Action

Precipitation due to chemical action may take place when the partial pressure of some of the gases in contact with the water is changed, when salts in waters of different composition react to give a slightly soluble salt, when oxygen enters the reservoir, and when the injected water reacts with substances in the reservoir rock. Only a few types of precipitates are likely to occur, viz., bicarbonate-carbonates, sulfates, organic compounds, sulfides, hydroxides, sulfur, and silicates.

Precipitation of carbonates and bicarbonates in water and brines.—The solubility of the bicarbonates in water is directly proportional to the carbon dioxide dissolved in the water which, in turn, is directly proportional to the partial pressure of carbon dioxide. The equilibrium reactions may be represented by the following equation:



where: M is one of the bivalent metals calcium, magnesium, barium, strontium, iron, or manganese. These bicarbonates are not stable in the solid state under normal conditions, and are stable in solution only in the presence of carbon-dioxide gas. The bicarbonate solution at equilibrium has a partial pressure of carbon dioxide above it, and the amount of bicarbonate in solution is directly proportional to this vapor pressure of CO_2 gas. The bicarbonates have a high maximum solubility; so that, under high pressures of carbon dioxide, considerable quantities of bicarbonates are in solution. The ratio of carbonic acid to dissolved carbon-dioxide gas is about 1 to 50, so that a large percentage of the carbon dioxide is simply dissolved in the waters. The solubility of the metal carbonate is immediately related to the concentration of carbonic acid. The bicarbonates are much more soluble than the carbonates. The quantitative relations which exist in the bicarbonate-carbon-dioxide equilibria are shown in Fig. 1, in which the partial pressure of carbon dioxide, in pounds per square inch, is plotted against the quantity of bicarbonate in solution in the presence of solid carbonate. Solubility and pH curves for carbon dioxide are also shown. The chart was made on log-log paper in order to cover the wide range of values with comparative accuracy on a chart of convenient size. The solid lines are based on data in the literature, whereas the broken lines are extrapolations from the known data.

The solubility of carbon dioxide is shown for the three temperatures: 0°, 25°, and 50° C. Data are not available for pressures less than 0.1 psi., although the solubility probably follows Henry's law rather closely for low pressures also. Two curves are given for its solubility in 65,000 and 175,000 p.p.m. sodium-chloride solution at 25° C. The latter concentration of sodium chloride cuts the solubility in half. The data on pH of carbon dioxide dissolved in pure water are conflicting. The pH scale shown on the chart is the author's opinion of the most probable values found in the literature.

Extensive and accurate data are available for the solubility of calcium, barium, and magnesium bicarbonates at 25° C. in water solutions in the presence of solid carbonates. The broken lines for the solubility of calcium bicarbonate at 0° and 150° C. were obtained by multiplying the solubility at 25° C., by the ratio of the solubility of carbon dioxide at 0° and 50° C. to that at 25° C. These curves should be considered as representing approximate values, and probably show a greater spread (solubility differential due to temperature) than actually exists.

Solubility data for ferrous, manganous, and strontium bicarbonates cover only a narrow high-pressure range of carbon-dioxide partial pressures. The curves cannot be extrapolated into the low-pressure range with accuracy. Ferrous bicarbonate is probably the least soluble of the bicarbonates on this chart throughout the range.

If tests are available on the injection water either before or after the project has been started, and if the physical conditions throughout the system are known, then the amount of precipitation can be estimated from the chart. Bicarbonate equilibria do not adjust themselves at once to physical changes. The rate of reaction is slow, so that one may be able to carry out physical changes so rapidly that a very small percentage of the precipitation actually takes place. The rate of reaction of the equilibria, shown in the foregoing equation (1), needs to be studied more thoroughly. Suffi-

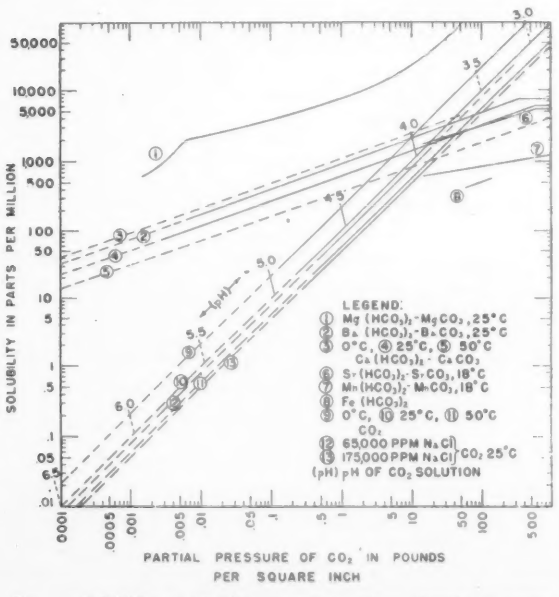


Fig. 1—Solubility of bicarbonates and carbon dioxide in water

Why

STAINLESS TYPE 316

IN OIL EQUIPMENT?

Because stainless steel of this analysis COMBATS REDUCING ACID CONDITIONS in equipment handling sour crudes . . . because it has HIGH CREEP STRENGTH at elevated temperatures . . . because its molybdenum content helps PROTECT AGAINST PITTING in applications where even normal 18-8 grades can't take it . . . Type 316 is widely used in oil equipment.

Certain other stainless steels — Types 304, 347, 416, and 440, for example — are especially suited for tough oil field and refinery jobs. For many years Metal Goods has been building stocks of these alloys to meet the needs of the Oil Industry. Our ONE-STOP SERVICE ON STAINLESS STEELS now offers stocks of *all* the special analyses mentioned above, plus several others. For help on the choice of stainless alloys, for complete stocks and quick delivery — CALL ON METAL GOODS.

ONE-STOP SERVICE ON STAINLESS STEELS

IN HOUSTON, DALLAS, TULSA STOCKS

		STAINLESS TYPES		
SHEETS	SHAPES	302	304	416
BARS	PIPE	303	316	440
PLATES	FITTINGS		347	
TUBES	FASTENINGS			

AVAILABLE ON SPECIAL ORDER

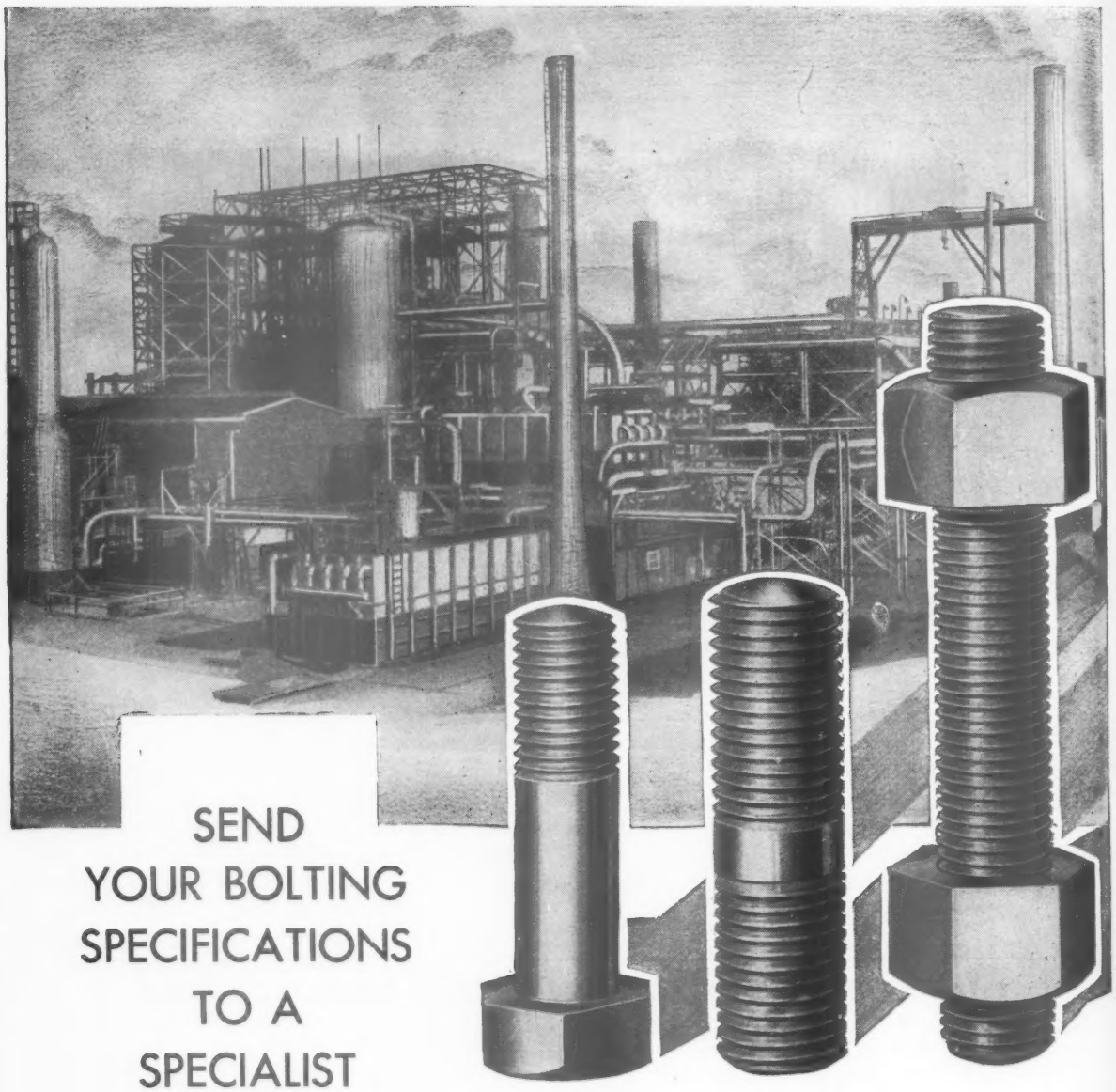
STAINLESS CASTINGS—STATIC & CENTRIFUGAL
WOVEN WIRE MESH — CHAIN — FORGINGS

METAL GOODS CORPORATION · MGC · QUALITY METALS

METAL GOODS CORPORATION

St. Louis 2239 BROWN AVE. · Kansas City 1701 BALTIMORE · Tulsa 19 E. CAMERON · Houston 16 DRENNAN ST. · Dallas 2500 So. ERVAY ST. · New Orleans 413 CANAL BLDG.

XUM*



SEND YOUR BOLTING SPECIFICATIONS TO A SPECIALIST

ERIE, for many years, has maintained high standards by stressing quality in the manufacture of special bolts and studs, a large portion of which are used by the oil refining industries in the manufacture of regular and high octane gasoline.

Because of this background, it is only natural that leading refinery builders place their confidence in **ERIE** as their source for high temperature and high pressure bolting material.

As a result of this acceptance, **ERIE** today is recognized as one of the leading manufacturers of specials in the industry.

It will pay you to send us your inquiries which will be given our best attention.

ERIE BOLT & NUT CO.

ERIE, PA.

STUDS • BOLTS • NUTS ~ ~ ALLOYS • STAINLESS • CARBON • BRONZE

cient data to complete the chart accurately would be very valuable in calculating the amount of plugging off of sands due to carbonate precipitation, and in indicating feasible methods of preventing precipitation. Data are not available on the solubility of the bicarbonates in salt water. Three major factors will affect their solubility: (1) Carbon dioxide is less soluble in salt solutions than in pure water, and this will tend to decrease the solubility of the bicarbonates; also the presence of a common metallic ion in higher concentration in the brine will decrease the solubility. (2) The tendency for a soluble unlike salt to increase the solubility of a slightly soluble salt will increase the solubility of the bicarbonate. (3) Calcium carbonate will probably be less soluble in brine containing calcium chloride than in pure water, whereas ferrous bicarbonate will probably be more soluble in most brines.

Precipitation of sulfates in water and in brines.—Barium, strontium, and calcium sulfates are sufficiently low in solubility (see Table 2) that they may precipitate out in injection-water systems. Barium chloride is present in about half of the brines analyzed in West Virginia to an extent that the introduction of a sulfate-containing water would cause barium-sulfate precipitation in the reservoir at the interface between the two waters. The equation is:

$$\underset{\text{brine}}{BaCl_2} + \underset{\substack{\text{injected}\\\text{water}}}{CaSO_4} \rightarrow \underset{\text{solution}}{CaCl_2} + \underset{\text{precipitate}}{BaSO_4} \qquad (2)$$

Barium sulfate is considerably more soluble in salt solutions than in pure water, and the barium sulfate is more soluble with increasing salt concentration. Fig. 2 shows the solubility of barium sulfate in solutions of magnesium, aluminum, and ferrous chlorides. Of course, the presence of excess barium ion will decrease the solubility due to common ion effect, although usually the barium sulfate will be more soluble in the brine than in pure water. The common ion effect is shown in Fig. 3 for calcium sulfate in the presence of calcium chloride. The solubility of these slightly soluble sulfates in brines of various concentrations should be determined. Surprisingly high solubilities in strong brines may be expected. Reservoirs which have been repressured with air may have sulfate-containing waters which will precipitate both calcium and barium sulfate on injection of brines from other horizons. Details will be given hereinafter under oxidation reactions.

Precipitation of sulfides in water and in brines.—The shallow ground waters may contain sulfides, which are produced by the action of sulfate-reducing bacteria on sulfates. Many of the Lower Devonian and deeper sediments contain considerable quantities of sulfides. Sufficient metallic ions whose sulfides hydrolyze are present in the brines so that a large part of the sulfide may occur as hydrogen sulfide, either as gas or in solution. An equilibrium is set up, as illustrated in Equation 3, similar to the carbonic-acid-bicarbonate reaction. If both carbon dioxide and hydrogen sulfide are present, one equilibrium affects the other.

$$BaS + 2H_2O \rightleftharpoons \underset{\substack{\text{dissolved}\\\downarrow\uparrow\\H_2S\\\text{gas}}}{Ba(OH)_2 + H_2S} \qquad (3)$$

Ferrous and manganous sulfides are very insoluble in water, and they precipitate out when iron and manganese-containing waters mingle with sulfide water according to the following equation:

$$Fe(HCO_3)_2 + H_2S \rightarrow \underset{\substack{\text{black}\\\text{colloidal}\\\text{precipitate}}}{FeS} + 2H_2CO_3 \qquad (4a)$$

$$Mn(HCO_3)_2 + H_2S \rightarrow \underset{\substack{\text{pink}\\\text{precipitate}}}{MnS} + 2H_2CO_3 \qquad (4b)$$

The action of hydrogen-sulfide-containing waters on iron pipe and equipment also produces ferrous sulfide as follows:

$$Fe + H_2S \rightarrow \underset{\substack{\text{black}\\\text{colloidal}\\\text{precipitate}}}{FeS} + H_2 \qquad (5)$$

If ferric iron is present in the water or reservoir, hydrogen sulfide will reduce it to ferrous iron and precipitate out sulfur as well as ferrous sulfide as follows:

$$Fe_2(SO_4)_3 + 3H_2S \rightarrow \underset{\substack{\text{black}\\\text{colloidal}\\\text{precipitate}}}{2FeS} + 3H_2SO_4 + \underset{\substack{\text{yellow}\\\text{colloidal}\\\text{precipitate}}}{S} \qquad (6a)$$

$$Fe_2O_3 + 3H_2S \rightarrow \underset{\substack{\text{black}\\\text{colloidal}\\\text{precipitate}}}{2FeS} + 3H_2O + \underset{\substack{\text{yellow}\\\text{colloidal}\\\text{precipitate}}}{S} \qquad (6b)$$

The solubility of these sulfides in brines is not known, although it is safe to say that they are more soluble in brines than in water.

Oxidation Reactions

Injection waters may contain two metallic ions: ferrous iron and manganous manganese, and one negative ion: sulfide, that oxidize readily and form slightly soluble precipitates. Manganese is seldom present in amounts which would cause plugging off of the reservoir. Ferrous iron is quite common, although not always present in amounts suffi-

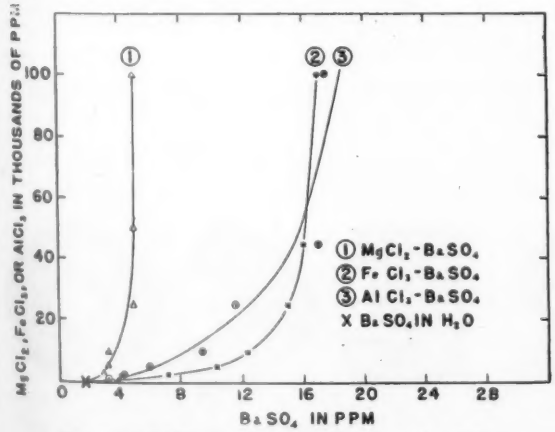


Fig. 2—Solubility of barium sulfate in salt solution

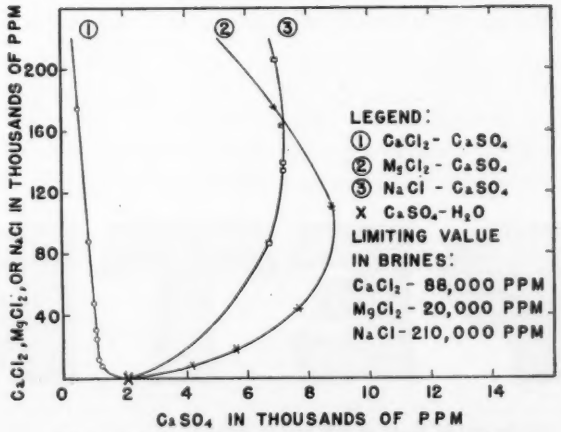
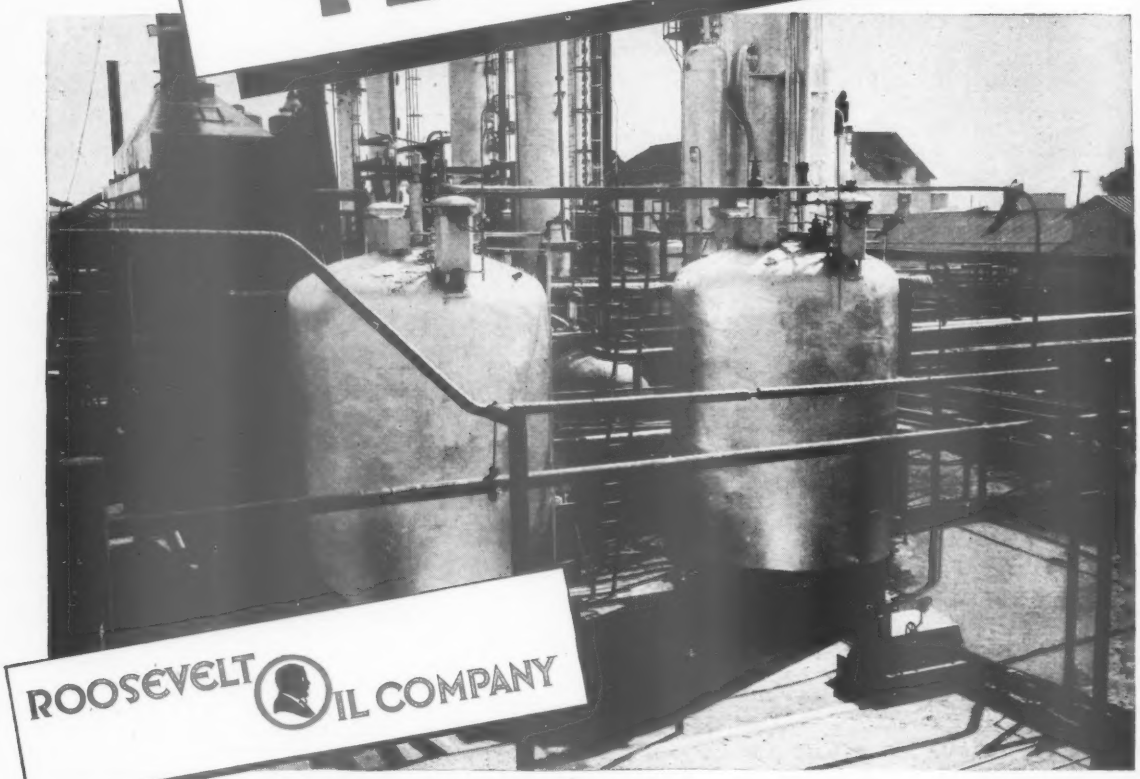


Fig. 3—Solubility of calcium sulfate in salt solution

MICHIGAN REFINERS

...INCREASE RUNS, PROTECT EQUIPMENT WITH PETRECO



The above picture shows the Petreco Desalting installation of the Roosevelt Oil Company of Mt. Pleasant, Michigan. Referring to the performance of this equipment an officer of the company remarks:

"These two Desalter units handle approximately 5000 bbls. of crude oil per day. The crude charge averages from 60 to 150 lbs. of salt per 1000 bbls. of crude and salt removal averages approximately 93%. Use of these units enables us to run our naphtha unit, which receives our crude charge, from 90 to 100 days before washing and cleaning is necessary. We have also found that the use of the Desalters has made a material saving in operation, due to longer life on exchanger tubes, still tubes and condenser coils."

PETROLEUM RECTIFYING COMPANY
5121 South Wayside Drive, Houston 1, Texas
530 West Sixth Street, Los Angeles 14, California
648 Edison Building, Toledo 4, Ohio
Representatives in principal production and refining centers

PETRECO

DESALTING · *Electrical Processes* · DEHYDRATING

cient to be harmful. Its concentration increases due to corrosion of iron pipe and fittings. Iron is seldom present in underground waters in amounts in excess of its solubility as ferrous bicarbonate, and its most important reaction is that of bicarbonate decomposition (as shown in Fig. 1 and in Equation 1) plus the oxidation reaction in the presence of dissolved oxygen. The latter reaction is:

$$12Fe(HCO_3)_2 + 3O_2 + 6H_2O \rightarrow \underset{\text{unstable}}{8Fe(HCO_3)_3} + 4Fe(OH)_3 \quad (7)$$

$$\downarrow$$

$$8Fe(OH)_3 + 24CO_2$$

colloidal precipitate

The solubility of ferric hydroxide in pure water is extremely low, although the exact value is not known. Its solubility in solutions of carbon dioxide is not known. Some surface or near-surface waters may contain ferric and ferrous sulfate in solution; so that calcium, strontium, or barium sulfate may precipitate out on contact of these waters with brines according to Equation 2. If dissolved oxygen is present, as it frequently is, ferrous iron will oxidize to give insoluble ferric hydroxide. The equation is:

$$12FeSO_4 + 3O_2 + 6H_2O \rightarrow \underset{+\ 24H_2O}{4Fe(SO_4)_3} + \underset{\text{colloidal precipitate}}{4Fe(OH)_3} \quad (8)$$

$$\downarrow\uparrow$$

$$8Fe(OH)_3 + 12H_2SO_4$$

colloidal precipitate

The hydrolytic equilibrium reaction will depend on the pH of the solution. The removal of the sulfuric acid by action on limestone ($CaCO_3$) will precipitate all of the iron.

Hydrogen sulfide is oxidized by dissolved oxygen to water and free sulfur as follows:

$$2H_2S + O_2 \rightarrow 2H_2O + \underset{\text{white to yellow colloidal precipitate}}{2S} \quad (9)$$

The sulfur is very finely divided, and effectively seals off the reservoir. Once a reservoir is sealed off with colloidal sulfur, the latter is very difficult to remove.

Sulfides are also oxidized to sulfates, to such an extent in some cases as to cause precipitation of insoluble sulfates, as indicated in Equation 2.

$$H_2S + 2O_2 \rightarrow H_2SO_4 \quad (10a)$$

$$BaS + 2O_2 \rightarrow \underset{\text{precipitate}}{BaSO_4} \quad (10b)$$

The oxidation of the mineral, pyrite, causes excessive acidity and sulfate precipitation. Most reservoirs which have or are being repressured with air, or water containing dissolved air, will contain considerable oxidation products of pyrite as follows:

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2FeSO_4 + 2H_2SO_4 \quad (11a)$$

$$+$$

$$\tfrac{1}{2}O_2$$

$$+$$

$$5H_2O$$

$$\downarrow$$

$$2Fe(OH)_3 + 2H_2SO_4$$

precipitate

$$FeSO_4 + CaCl_2 \rightarrow FeCl_2 + \underset{\text{precipitate}}{CaSO_4} \quad (11b)$$

If brines are injected into such a reservoir, then calcium, barium, and strontium sulfates will precipitate out in the pore space. The amount of precipitate will depend on the quantity of pyrite previously oxidized to sulfate and the quantity of calcium, barium, and strontium in the brine. Considerable plugging effects may result which will restrict the flow of fluids in and out of the wells, and may cause bypassing of oil reservoirs. Oxidation of pyrite to sulfate may occur naturally in reservoirs close to the outcrop.

Biological Action

Algae and bacteria grow and reproduce in most waters that are used for injection when the water is inoculated with the organism. These organisms, both living and dead, are small and remain suspended in the water. They plug off the pores of the sand and walls of the well. They grow much more rapidly in warm water; therefore, they may be more prevalent in surface waters and storage tanks in summer. The organisms may continue to grow and spread in the water injected in the reservoir. Their plugging-off effect unquestionably decreases the injectivity and productivity of the wells. Some bacteria cause chemical reactions to take place which cause precipitation of salts. Sulfate-reducing bacteria reduce sulfates to sulfides, with subsequent precipitation of insoluble sulfides (Equation 4) and free sulfur (Equation 6).

$$CaSO_4 \rightarrow CaS + 4O \quad (12)$$

The oxygen is used by the bacteria to produce energy through oxidation of organic matter, with subsequent release of carbon dioxide. The carbon dioxide upsets the carbonate-bicarbonate equilibria in the water, with the possibility of a plugging-off effect by advancing water.

Summary

The salts in interstitial waters are mostly chlorides, sulfates, and bicarbonates of sodium, calcium, magnesium, potassium, strontium, and barium. Other ions that may be present are bromide, iodide, sulfide, phosphate, silicate, carbonate, iron, manganese, aluminum, lithium, and ammonium.

Physical changes which may cause precipitation or solution are temperature, pressure, evaporation, and condensation.

Chemical reactions cause precipitates to form because of physical change, intermingling of waters containing different salts, oxygen, or biological action. These precipitates are usually carbonates, sulfates, sulfides, hydroxides, and biological residues.

Acknowledgment

It was originally intended to include an extensive bibliography with this paper. The bibliography on secondary recovery, published in the Proceedings Twenty-fourth Annual Meeting of the American Petroleum Institute, Sec. 4 (Production), p. 219-61 (1943) adequately covers the subject. The author has also drawn on numerous standard references, such as International Critical Tables and scientific journals, for solubility data.

R. F. Schuderer has resigned from Gulfshore Oil Co. to join Houston Natural Gas Corp. as production superintendent in the Alice, Tex., area. Schuderer was production superintendent for P. R. Rutherford Oil Co. several years.

D. A. McDougald, assistant to the president of Sinclair Petroleum Co., has left New York for Ethiopia, where he will open an office at Addis Ababa. A Sinclair statement says this is the first step in carrying out an agreement with the Ethiopian Government under which the company is to develop a petroleum concession recently acquired.

TYPE E-2T STEAM TURBINE

PYLE-NATIONAL STEAM TURBINES

75,000 Pyle-National Steam Turbines in service today throughout industry reflect their high quality performance and assure the lowest possible maintenance costs.

In the oil country they are the accepted standard for rig power and general utility purposes.

These sturdy, dependable and economical units are available in sizes from ¼ to 150 horsepower and a variety of standard types can be furnished for applications involving either rotation and for various steam pressures.

Full particulars and prices glady furnished on request.

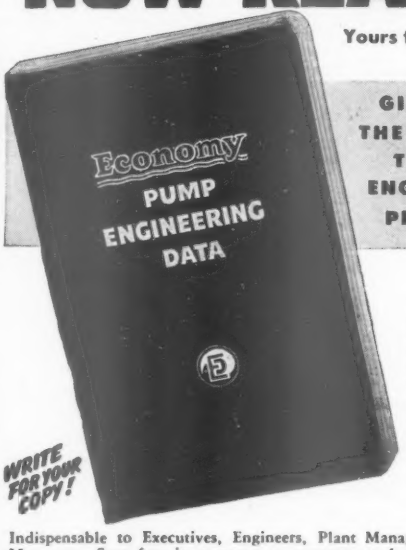
BETTIS SALES COMPANY
1507 MAURY ST.
HOUSTON 10, TEXAS, U. S. A.

A LARGE MANUFACTURER HAVING REPRESENTATION AND OFFICES IN ALL OIL PRODUCING STATES, CALLING ON FIELD SUPERINTENDENTS, PURCHASING AGENTS, AND WAREHOUSEMEN, DESIRES TO CONTACT A MANUFACTURER WHO DESIRES SALES REPRESENTATION FOR HIS PRODUCT.

Box A-842
The Oil and Gas Journal
Tulsa 1, Okla.

NOW READY

Yours for the asking



GIVES YOU THE ANSWERS TO PUMP-ENGINEERING PROBLEMS

A timely contribution to industry—416 pages of factual data just when vital post-war pump problems require authentic facts, sound experience and advanced engineering practice.

WRITE FOR YOUR COPY!

Indispensable to Executives, Engineers, Plant Managers, Maintenance Men, etc. Sent free in response to requests on business letterheads.

Please send me free copy of Economy Pump Engineering Data Book.
Name.....
Title.....
Firm.....
Address.....

ECONOMY PUMPS, INC.
HAMILTON, OHIO • U. S. A.

PETROLEUM vs. PLUTONIUM

*by Clark Goodman**

A.P.I.

Introduction

THE familiar saying "a little knowledge is a dangerous thing" is particularly apropos in the case of atomic energy. Following President Truman's announcement of the bombing of Hiroshima on August 6, 1945, the air was filled with radio reports. Virtually every newspaper and magazine in the country followed with feature articles on atomic power. These are continuing and, in addition, we are being exposed to a plague of books on the subject. In the sweep of publicity, the facts have often been ignored or hidden beneath a flood of overenthusiastic extrapolation and speculation. A typical example is the prediction of a well-known science editor and Pulitzer prize winner that in the "atomic age" ahead "instead of filling the gasoline tank of your automobile two or three times a week, you will travel for a year on a pellet of atomic energy the size of a vitamin pill. That same pill will be enough to heat your house for the winter."

*Massachusetts Institute of Technology, Cambridge, Mass.

It seems particularly timely that a factual report be made to the petroleum industry. Only on the basis of these facts can anything approaching an accurate evaluation be made of the present and future competition to petroleum of this new source of energy.

Fundamental Principles

The study of atomic energy constitutes part of the general field of nuclear physics. In this, as in all branches of science, the principles involved are described through a specialized terminology. Unfamiliar words and symbols often cloak familiar ideas. The first step in the understanding of atomic energy is a definition of the specialized words and symbols used.

Fig. 1 is only one of the various possible systematic arrangements of the elements that occur in nature or have recently been produced. The elements are arranged in order of increasing atomic number, indicated by the figure immediately below the symbol of each element. The letter Z will be used to represent this number. In chemistry Z generally is considered to be the number of negatively charged electrons contained in an atom of a given element. The periodicity of the table corresponds to a periodicity in the chemical properties which is the result of the arrangement of the

0	I	II	III	IV	V	VI	VII	VIII			I b	II b	III b	IV b	V b	VI b	VII b	VIII b
1.0087 n neutron 0	1.0080 H 1																	4.003 He 2
4.003 He 2	6.940 Li 3	9.02 Be 4	10.82 B 5	12.010 C 6	14.008 N 7	16.000 O 8	19.00 F 9	20.183 Ne 10										
20.183 Ne 10	22.997 Na 11	24.32 Mg 12	26.97 Al 13	28.06 Si 14	30.98 P 15	32.06 S 16	35.457 Cl 17	39.944 A 18										
39.944 A 18	39.096 K 19	40.08 Ca 20	45.10 Sc 21	47.90 Ti 22	50.95 V 23	52.01 Cr 24	54.93 Mn 25	55.85 Fe 26	58.94 Co 27	58.69 Ni 28	63.57 Cu 29	65.38 Zn 30	69.72 Ga 31	72.60 Ge 32	74.91 As 33	78.96 Se 34	79.916 Br 35	83.7 Kr 36
83.7 Kr 36	85.48 Rb 37	87.63 Sr 38	88.92 Y 39	91.22 Zr 40	92.91 Cb 41	95.95 Mo 42		101.7 Ru 44	102.91 Rh 45	106.7 Pd 46	107.88 Ag 47	112.41 Cd 48	114.76 In 49	118.70 Sn 50	121.76 Sb 51	127.61 Te 52	126.92 I 53	131.3 Xe 54
131.3 Xe 54	132.91 Cs 55	137.36 Ba 56	138.9 * La 57	178.6 Hf 72	180.88 Ta 73	183.92 W 74	186.31 Re 75	190.2 Os 76	193.1 Ir 77	195.23 Pt 78	197.2 Au 79	200.6 Hg 80	204.39 Tl 81	207.21 Pb 82	209.0 Bi 83	(210) Po 84	85	222 Rn 86
222 Rn 86	87	226.05 Ra 88	(227) Ac 89	232.12 Th 90	231 Pa 91	238.07 U 92	(239) Np 93	(239) Pu 94										
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

140.13 Ce 58	140.92 Pr 59	144.27 Nd 60	Il 61	150.43 Sm 62	152.0 Eu 63	156.9 Gd 64	159.2 Tb 65	162.46 Dy 66	164.94 Ho 67	167.2 Er 68	169.4 Tm 69	173.04 Yb 70	174.99 Lu 71	*Rare Earth Elements

1945

Fig. 1—Periodic table of the elements. The symbols for the elements have been arranged in one of the conventional forms of the periodic table. The atomic number, immediately below the symbol, indicates the number of protons in the nucleus, or the number of electrons surrounding the nucleus in the normal atomic state. The chemical atomic weight listed immediately above the symbol is the international value as of 1945, based on oxygen as 16.0000

electrons in atomic shells or groups. Specialists in X-rays call these K, L, M, etc., shells.

Nuclear physicists think of the atomic number Z as the number of positively charged particles, called protons, contained in the core or nucleus of an atom of a given element. As all atoms are normally electrically neutral, the number of electrons equals the number of protons, and it makes no difference which of the two definitions is adopted for the atomic number. However, there is one important distinction between these two points of view. Atoms may gain or lose electrons without changing their atomic number, and hence, their position in the periodic table; but a change in the number of protons means a change in the atomic number which, of course, shifts the position of the atom in the periodic table. This shift results in a corresponding modification of the chemical properties of the atom; i.e., it is an atom of a different element. An example may help in understanding this difference.

Protons in Mercury Nucleus

Mercury, Hg, is of atomic number 80; every mercury atom contains 80 protons in its nucleus, and normally there are 80 electrons surrounding the nucleus. One or more of these electrons can be stripped off without changing the atoms to those of neighboring elements. In fact, the ultraviolet light from a mercury-arc sun lamp results from just these changes in the mercury atoms. However, if one of the protons in a mercury atom is removed, the result is an atom of atomic number 79, which is gold, Au. Such transmutations of elements take place in very limited amounts in atom smashers such as the cyclotron, betatron, and the linear resonance accelerator, but economics are highly favorable toward mining the metal. In fact, it is cheaper to produce gold from platinum (Z = 78) than from mercury by atomic methods.

A second important number in the periodic table is the atomic weight, listed just above the chemical symbol. For convenience oxygen has been selected as the standard and arbitrarily assigned the exact chemical atomic weight 16.0000. The symbol A will be used for atomic weight. On this scale the lightest and simplest of elements, hydrogen, has an atomic weight of 1.0080. As Z = 1, hydrogen must contain only one proton in its nucleus. The single electron that swirls about this nucleus has a weight of only about 0.0005 units. Thus hydrogen nuclei are the charged particles, protons, that constitute building blocks of all nuclei, and the relative weight of each of these elementary particles before incorporation in such nuclei is 1.0075, i.e., slightly greater than 1.

The interlocking particles that bind the protons together, and prevent their flying apart by electrostatic repulsion, are electrically neutral, and for this reason are called neutrons.† They have an atomic number zero and, relative to oxygen, a weight of 1.0087, as shown in Fig. 1. All nuclei are considered to be made up of neutrons and protons only. However, for a given element, i.e., a given Z, the number of neutrons present may vary somewhat. This variation, of course, results in different weights for the individual atoms of the element, even though they all have the same number of protons. The name "isotope" is given to such modifications of the same element. Even hydrogen is not simple. Common hydrogen, referred to above, has a single proton in its nucleus, but there is a rare form of hydrogen that has both a proton and a neutron in its nucleus. For obvious reasons, this is called heavy hydrogen (or deuterium), and water containing an unusually high proportion of this hydrogen is called heavy water. Carbon consists of two isotopes: common carbon, with 6 protons and 6 neutrons, and a rare form containing 6 protons and 7 neutrons. As we shall have occasion to note later, uranium consists of 3 isotopes, a common form with 92 protons and 146 neutrons known as U^{238}, a rare variety with 92 protons and 143 neutrons known as U^{235}, and a very rare form with 92 protons and 142 neutrons known alternately as U^{234} or UII. Many elements, particularly those with odd Z, have only one isotope, whereas others have many different forms. Fig. 2 (omitted in this report) is a schematic representation of all the different isotopic forms found in nature. Tin seems to hold the record with 10 isotopes. Naturally with so many different isotopes present in various abundances, the average weight of a given element would not be expected to be a simple multiple of the weights of the constituent particles, the proton and the neutron. However, there is an additional explanation for the observed values of the atomic weights. The weight of an aggregation of neutrons and protons is always less than the sum of the weights of the separate particles. For example, the weight of 2 protons and 2 neutrons is $2 \times 1.0075 + 2 \times 1.0087 = 4.0324$, whereas the weight of helium (less 2 electrons) is seen from Fig. 1 to be 4.0029. This decrease of about 0.03 weight units takes place when the 4 constituent particles coalesce to form the helium nucleus. The nuclear reaction that expresses this fact can be written symbolically as:

$$2_1H^{1.0075} + 2_0n^{1.0087} \rightarrow {}_2He^{4.0029}$$

$$+0.03 \text{ atomic-weight unit} \quad (1)$$

The subscripts (1 for hydrogen, 0 for the neutron, and 2 for helium) are the corresponding atomic numbers or electric charge (+ being understood unless otherwise designated). The superscripts are the nuclear atomic weights. Two fundamental axioms in physics require that the sum of the subscripts (charges) on the left must equal the sum on the right, and the sum of the weights on the left must equal the sum on the right. The coefficients in front of the symbols must, of course, be included in these considerations. In the foregoing equation 0.03 atomic-weight unit must appear on the right to balance the weight on the left.

The Sources of Atomic Energy

Einstein postulated, and ample experimental evidence has since proved, that weight (or, more exactly, mass) and energy are equivalent and related by the simple expression:

$$\text{Energy} = \text{constant} \times \text{mass} \quad (2)$$

The proportionality constant in this relationship is so large that 1 lb. of matter is equivalent to 39×10^{12} B.t.u. (i.e., 39 million million B.t.u.). In terms of the foregoing equation, the production of a pound of helium from hydrogen + neutrons would liberate 29×10^{10} B.t.u. of heat energy. Alternately it would require the expenditure of this prodigious amount of energy to break 1 lb. of helium into hydrogen and neutrons; i.e., the helium nuclei are bound together with this amount of energy.

A simplified method of presenting this relationship is to rewrite the foregoing process as an exothermic equation similar to familiar chemical reactions:

$$2_1H^1 + 2_0n^1 \rightarrow {}_2He^4 + 65 \times 10^7 \text{ kcal}$$

$$\text{per mole } (29 \times 10^{10} \text{ B.t.u.}$$

$$\text{per lb. He}) \quad (3)$$

The superscripts have been rounded off to integers for convenience, although it is understood that the exact value in each case is that given in Fig. 1 less the weights of the atomic electrons.

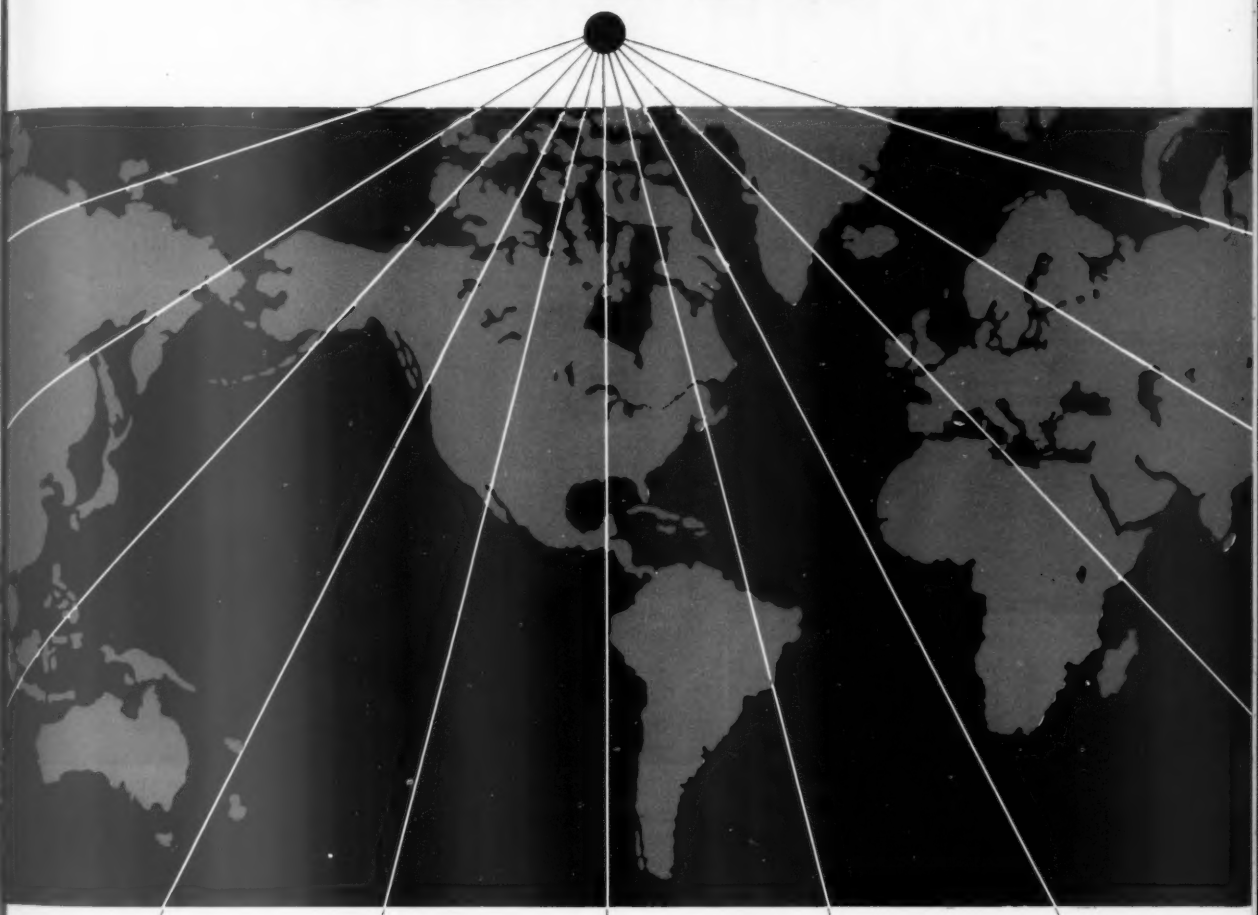
For comparison, the molecular reaction:

$$2H_2 + O_2 \rightarrow 2H_2O + 68 \text{ kcal}$$

$$\text{per mole} \quad (4)$$

†According to present theory the neutron and proton are merely slightly different forms of the same particle. Hence, it is not surprising that they are of nearly equal weight.

PETTY



. . . Focal Point of 20 Years World-Wide Geophysical Experience

Petty geophysical engineering facilities include the skill and knowledge gained by two decades of operations in fields throughout the world. This rich background of experience, augmented by the most advanced geophysical equipment, accurate interpretations and expert crews will result in authentic subsurface data on which to formulate your drilling plans.

PETTY GEOPHYSICAL ENGINEERING CO.

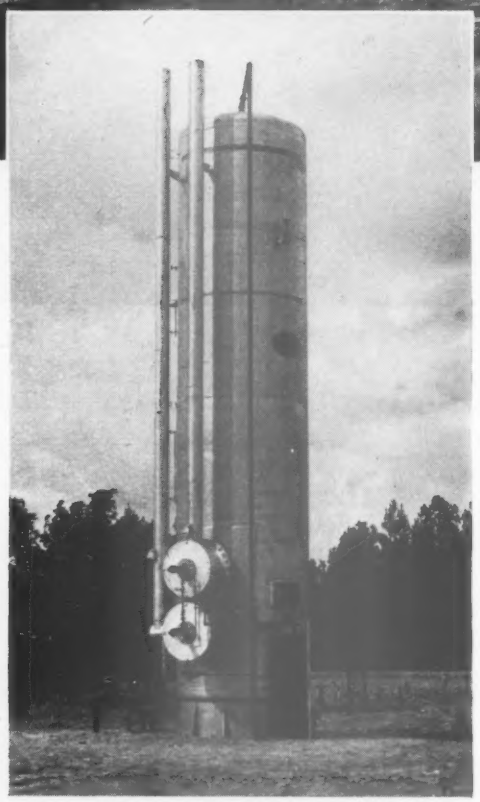
San Antonio, Texas

Seismic • Gravity • Magnetic Surveys

XUM

HEAT TREATING

EFFICIENTLY • DEPENDABLY • ECONOMICALLY



The Parkersburg Self-Insulating Treater eliminates need for separator, settling tank and heater. Ask for details.

The Parkersburg Immersion Type Horizontal Heater is the Industry's most modern method of converting the flow of crude oil from the separator to pipe line oil in your stock tanks. Its exclusive design employs a combination of radiation and convection heat transfer so as to insure uniform heating surface temperature and a minimum of deposits on the heating surface. Hot spots and large channeling volumes are eliminated. Combustion chamber and heat transfer tube are free to expand lengthwise. It is easier to assemble, dismantle and clean. Lighter weight and skid mounting makes easier hauling and installing. Your Parkersburg Representative will gladly furnish full details.

THE PARKERSBURG RIG & REEL CO.

PARKERSBURG & OCS PRODUCTS
GENERAL OFFICES, PARKERSBURG, W. VA.
Plants at Parkersburg, W. Va., Coffeyville, Kan.
District Offices
Dallas - Houston - Los Angeles - Tulsa
New York

OCS

PARKERSBURG

produces only about one ten-millionth as much heat. The corresponding mass decrease in this reaction is only 3.1×10^{-9} gram, which is undetectable by any known method of measurement.

The formation of helium from elementary particles symbolized above does not take place on the earth, because it requires very high temperatures. However, this reaction is believed to account for the tremendous thermal productivity of the sun, and takes place in six steps involving carbon and nitrogen as nuclear catalysts. A graphical representation of the relative binding energies of all known nuclei is given in Fig. 3. The binding energy per nuclear particle B/A is plotted against the atomic weight A for all known nuclei from hydrogen A = 1 to heavy nuclei of A = 240. Smooth average curves have been drawn, although there are some systematic variations from these, especially for low values of A where the main grouping of nuclei divides into two branches, with helium lying at the end of the upper branch and hydrogen at the end of the lower branch. As we have already seen, the binding energy of helium nuclei is much greater than that of hydrogen nuclei and neutrons separately. Hence the B/A for He lies well above that of H. The significance of the curve now becomes evident. Transformations which result in changes from a lower portion of the curve to an upper portion are exothermic, and vice versa. However, there is one important difference between the changes at low values of A as compared to those at high values. Certain heavy nuclei can be made to split into two or more fragments of medium atomic weight A at ordinary temperatures (0 — 200° C.). This process is known as nuclear fission, and the energy released by such a change has been designated as the fission energy in Fig. 3. Pound for pound, or on the basis of the number of nuclear particles involved, the fission of heavy nuclei generates about one-seventh as much energy as the formation of helium from hydrogen in the sun. It is small wonder that this process constitutes a potent source of energy.

Apparently, there is a minimal change in binding energy below which fission does not occur. Although nearly all of the heavy elements have been tested, fission apparently is appreciable only in those elements above about 210 in atomic weight. Of these elements only uranium and thorium occur in appreciable quantities in terrestrial materials. Their presence indicates that uranium and thorium must be relatively stable, otherwise they would have long since disappeared during the 3 ± 1 billion years since this planet was formed.

Radioactivity

As shown in Fig. 2, uranium and thorium are not completely stable, but undergo spontaneous transformations that result in elements of lower atomic weights. Radioactivity is the term used to describe these changes. In Fig. 3 the small shift from A = 238 to A= 206 for the uranium series, and from A = 232 to A = 208 for the thorium series, releases sufficient energy to account for all the internal-heat flux of the earth. As part of American Petroleum Institute Project 43, a study is being made to determine whether this energy has also been a factor in the genesis of petroleum. However, the present discussion is only indirectly related to this project.

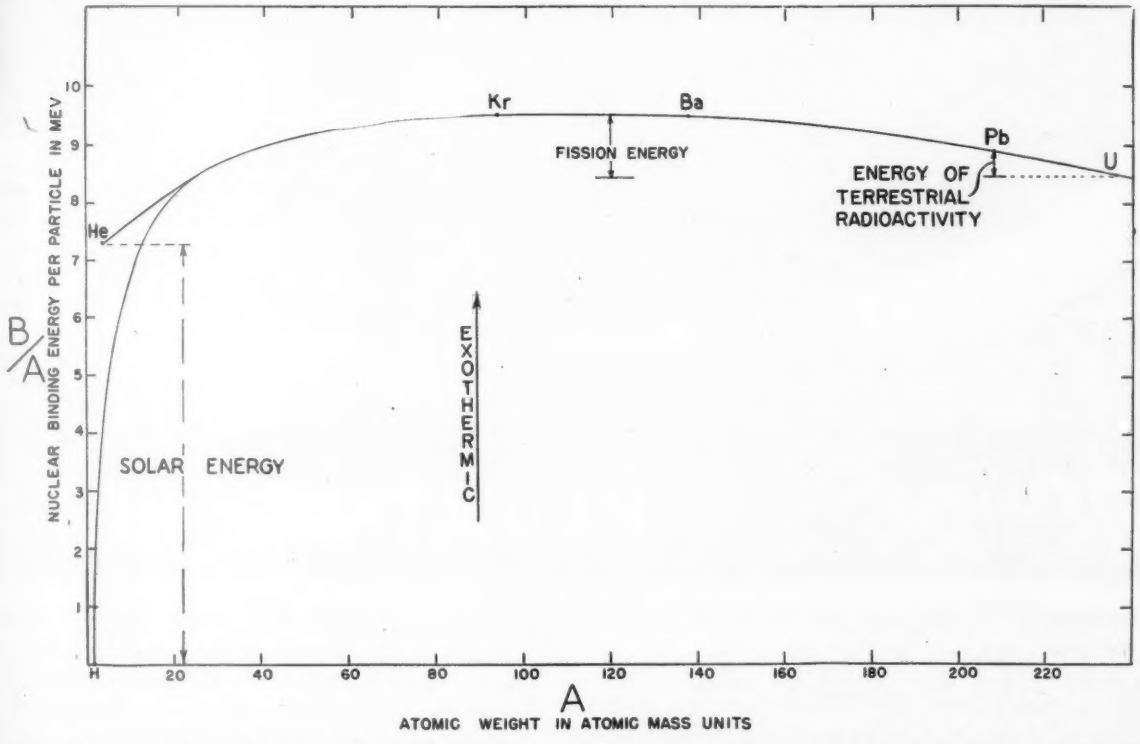
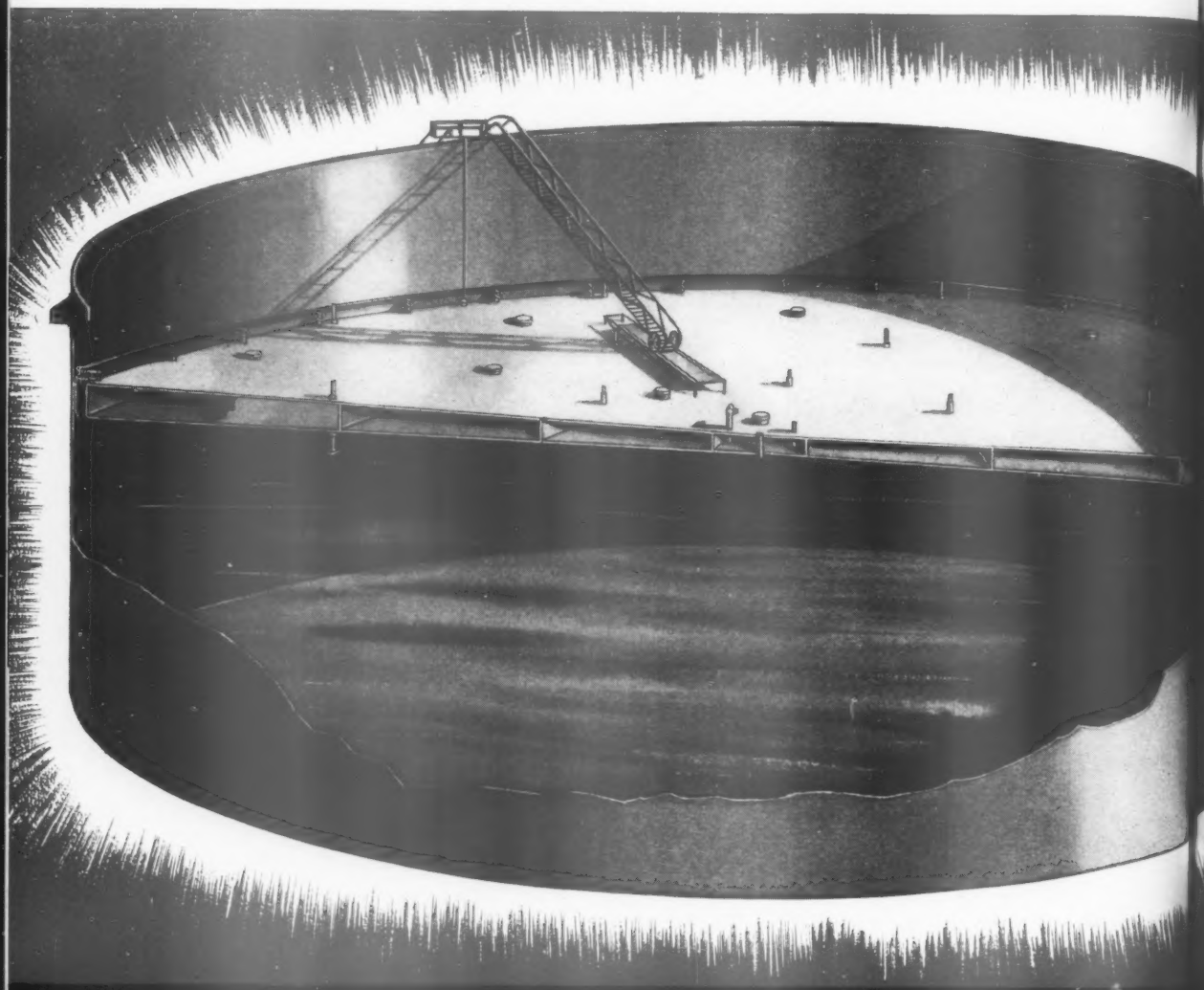


Fig. 3—Approximate relation between the binding energy per particle B/A and the atomic weight A of nuclei. Nuclear transformations that result in a change from a lower value of B/A to a higher value are exothermic. The upper branch in the curve at low values of A results from the greater binding energy of nuclei containing an integral multiple of alpha particles (two protons plus two neutrons), such as $_2He^4$, $_6C^{12}$, and $_8O^{16}$. The general rise in the center of the curve is attributable to the somewhat greater binding energy per particle of medium-weight nuclei, as compared to light or heavy nuclei. The source of solar energy is considered to be the nuclear transformation of hydrogen to helium at the high temperature and pressure within the sun. The energy released by the heavy, naturally radioactive elements uranium and thorium corresponds to the relatively small change indicated on the right. The release of fission energy by elements of atomic number greater than 210 corresponds to a decrease in A, such as uranium splitting into fission products barium and krypton

CHICAGO BRIDGE & IRON

a complete line of evaporation



the HORTON FLOATING ROOF...

Construction and operating features of the Horton Floating Roof . . . a double-deck roof of improved design.

Double-deck construction insulates liquid and prevents boiling. This extends the range of products that can be stored in tanks with floating roofs.

Entire bottom of deck is in contact with liquid, reducing corrosion.

Practically unsinkable and extremely stable.

Deck drains rapidly to screened opening at center. Water collecting on the roof when drain is closed does not lessen stability.

Open sump draining rain water into tank, pipe drain or flexible hose optional. No siphon necessary with open sump.

Bottom of deck coned up toward center, facilitating the venting of air trapped under deck when the roof is floated or the collecting of entrained vapors which are held until they recondense.

Top of deck smooth and free of obstruction.

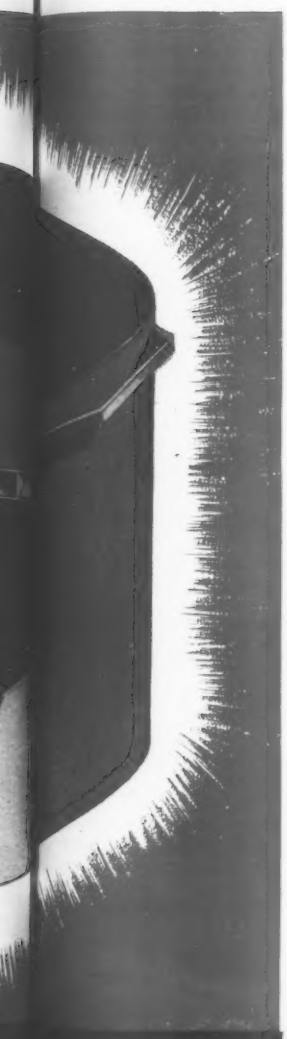
Space between deck and tank shell closed by effective seal which forms a long sliding contact with tank shell. Secondary seals supplied when product stored requires added protection.

Installed complete with adjustable supports, gauge hatch, bleeder vent, drain, emergency drain, and manholes.

Embodies the engineering experience and skill acquired by Chicago Bridge & Iron Company in designing, fabricating and erecting floating roofs since 1923.

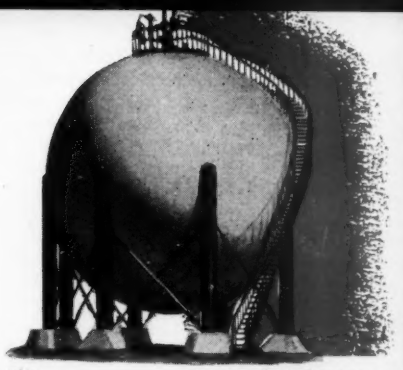
XUM

COMPANY builds
saving equipment

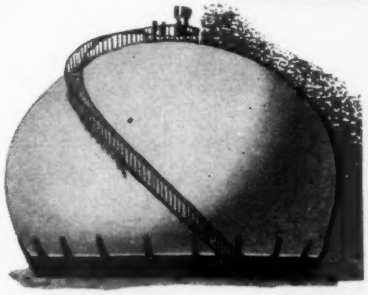


ADVANCED technical processes in refining and blending have created the need for more efficient evaporation saving equipment. Oil companies can materially reduce the evaporation of volatile hydrocarbons during the storage periods between production, refining, blending, and marketing, with the equipment shown here. These products embody the engineering experience and skill acquired during twenty-two years of designing, fabricating, and erecting evaporation saving equipment for the petroleum industry.

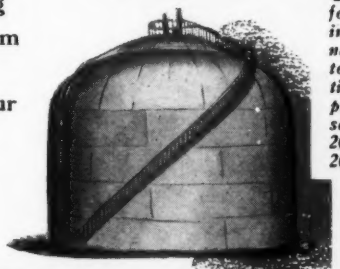
We invite you to write our nearest office for further information on these products.



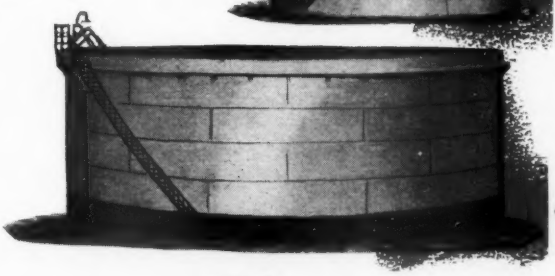
HORTONSPHERES . . . *are used by the petroleum industry for the storage of highly volatile liquids and gases. They prevent evaporation loss by allowing pressure to build up inside the tank instead of venting. Available in standard capacities from 1,000 to 25,000 bbls. for liquids, and from 20 to 65 ft. in diam. for gases.*



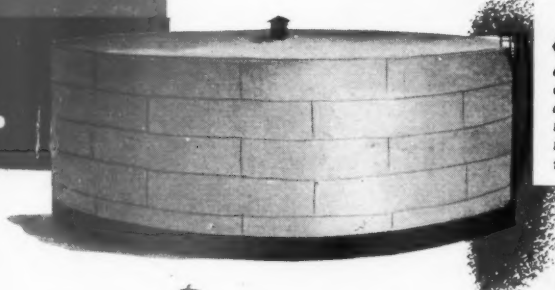
HORTONSPHEROIDS . . . . . . *for storing hydro-carbons ranging in volatility from motor fuel to natural gasoline. Smooth Hortonspheroids are built in capacities of 2,500 to 40,000 bbls. for pressures from 2½ to 35 lbs. per sq. in. and noded designs from 20,000 to 120,000 bbls. for 2½ to 20 lbs. pressure.*



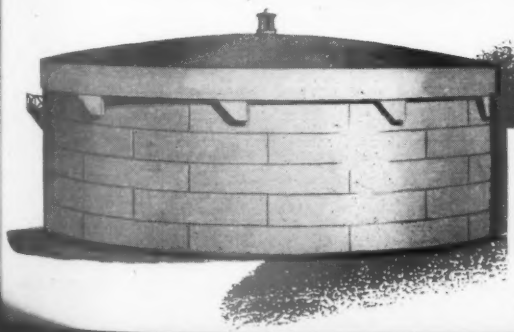
HEMISPHEROIDS . . . . . . *provide an economical means of storing liquids requiring pressures of only 2½ to 10 lbs. per sq. in. to stop standing storage losses under normal operating conditions. Built in sizes from 2,500 to 20,000 bbls. (Noded Hortonspheroids are used for capacities over 20,000 bbls.)*



WIGGINS* FLOATING ROOFS . . *are supplied for installations where the volatility of the oil does not require the insulating qualities of the Horton roof. These roofs, in varying specific forms, have been used extensively on tanks storing sour crude oil and will hereafter be available in forms particularly well adapted for this use.*



WIGGINS BREATHER* ROOFS . . . *are used to reduce breathing losses on standing storage tanks. They are particularly recommended for tanks 60 ft. in diameter or larger that are kept full or nearly full most of the time.*



HORTON LIFTER ROOFS . . . . . . *reduce evaporation losses from standing storage or slow working tanks. The vapor spaces of several adjoining cone roof tanks are often connected to the vapor spaces of a tank with a lifter roof.*

CHICAGO BRIDGE & IRON COMPANY

Atlanta • Birmingham • Chicago • Cleveland
Havana • Houston • Los Angeles • New York
Philadelphia • San Francisco • Tulsa • Washington

** Chicago Bridge & Iron Company Trade Mark*

XUM

The alpha ($_2He^4$), beta ($_{-1}e^0$), and gamma (γ, electromagnetic radiation) rays emitted by the uranium series and the thorium series may have modified organic source materials in sediments to produce petroleum.

The emission of these radiations by an individual atom occurs in an extremely short time. However, the likelihood that one of these rapid changes will take place is quite small. For this reason an aggregate of uranium or thorium atoms requires several billion years to decrease in number by 50 per cent. Hence the heat generation within the earth is slow even in terms of geologic time.

The emission of an alpha ray by radioactive decay is similar to nuclear fission in that both processes result in the splitting of a nucleus into two parts, forming two new nuclei. However, these related phenomena differ in a number of important respects.

Nuclear Fission

In the first place, radioactivity decay is spontaneous, and not susceptible to any control. On the other hand, to produce fissions it is necessary to strike the nucleus with a particle or with radiation. There are a number of such nuclear detonators, but neutrons are by far the most effective. The absence of electric charge ($Z = 0$) enables these particles to penetrate easily; whereas protons, deuterons, and alphas—being positively charged—are strongly repelled by the large electrostatic fields of heavy nuclei.

The probability of a neutron-producing fission in a uranium or thorium nucleus is dependent upon a number of factors, not the least in importance being the velocity of the neutron. In fact, the less abundant isotope * $_{92}U^{235}$ is very infrequently split by other than relatively slowly moving neutrons, the probability of fission being inversely proportional to the velocity of the neutrons. Such low-velocity neutrons are called "thermal neutrons," because they move at the speed of molecules in a gas at room temperature. On the other hand, thorium nuclei ($_{90}Th^{230}$ only) and $_{92}U^{238}$ nuclei undergo fission under neutron bombardment only when the neutrons have high energies, called "fast neutrons." With slow and intermediate-velocity neutrons the following transformations occur:

$$_{90}Th^{232} + {}_0n^1 \text{ (slow)} \rightarrow {}_{90}Th^{233} + \gamma \quad (5)$$

$$_{92}U^{238} + {}_0n^1 \text{ (slow and intermediate)} \rightarrow {}_{92}U^{239} + \gamma \quad (6)$$

The product nuclei do not undergo fission, but are less stable than the original nuclei, being beta-radioactive with half lives of 26 min. and 23 min., respectively.

The action of fast neutrons on $_{90}Th^{232}$ and $_{92}U^{238}$, and of slow neutrons on $_{92}U^{235}$, results in fission into two slightly unequal nuclei. The process is highly exothermic and considerably more complex than any of the foregoing reactions. One possible sequence for $_{92}U^{235}$ will serve to illustrate the nature of the changes involved:

$$_{92}U^{235} + {}_0n^1 \text{ (slow)} \rightarrow {}_{92}U^{236} \rightarrow {}_{56}Ba + {}_{36}Kr + 2{}_0n^1 + \text{HEAT} \quad (7)$$

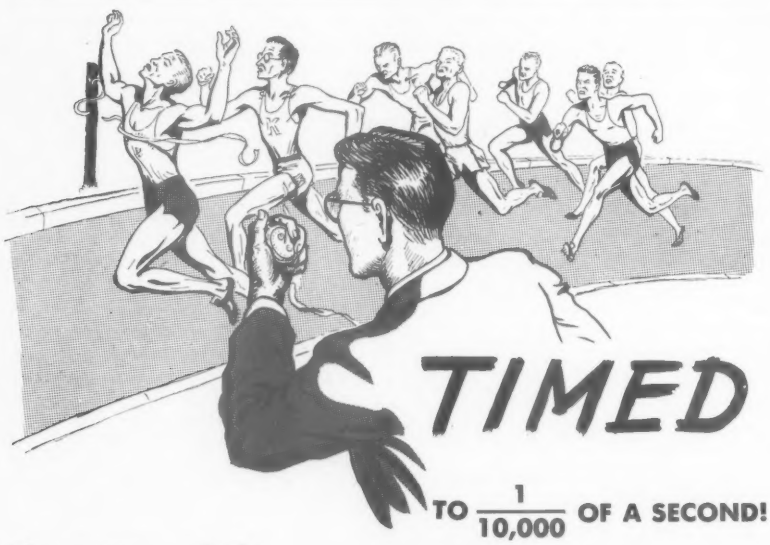
This reaction occurs almost instantaneously and, hence, is explosive in character. The fission products, $_{56}Ba$ and $_{36}Kr$, fly apart with tremendous velocities. Because these nuclei contain too many neutrons to be stable,† several beta-disintegrations and possibly a neutron-decay are necessary before stable nuclei are formed. These secondary changes occur relatively slowly, and are accompanied by the evolution of about one-fourth as much heat as the fission reaction.

Properties of Plutonium

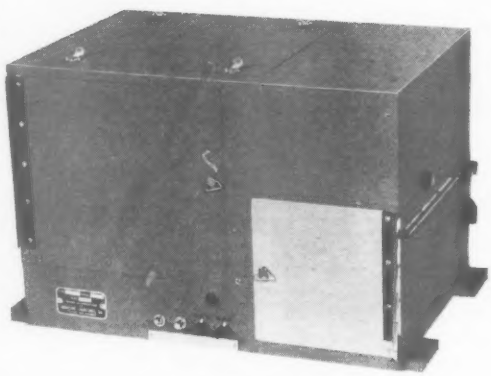
In the preceding section it was mentioned that slow and intermediate-velocity neutrons on $_{92}U^{238}$ produce a beta-radioactive isotope $_{93}U^{239}$.

*Uranium is composed of 0.7 per cent $_{92}U^{235}$ and 99.3 per cent $_{92}U^{238}$.

†The heaviest stable isotopes of these two elements are $_{56}Ba^{138}$ and $_{36}Kr^{86}$.



The accuracy of the E.L.I. Seismograph is known throughout the world. Time lines are produced on the E.L.I. Recording Oscillograph to an accuracy above 1/10,000 of a second in order to insure dependable answers on seismograph records.

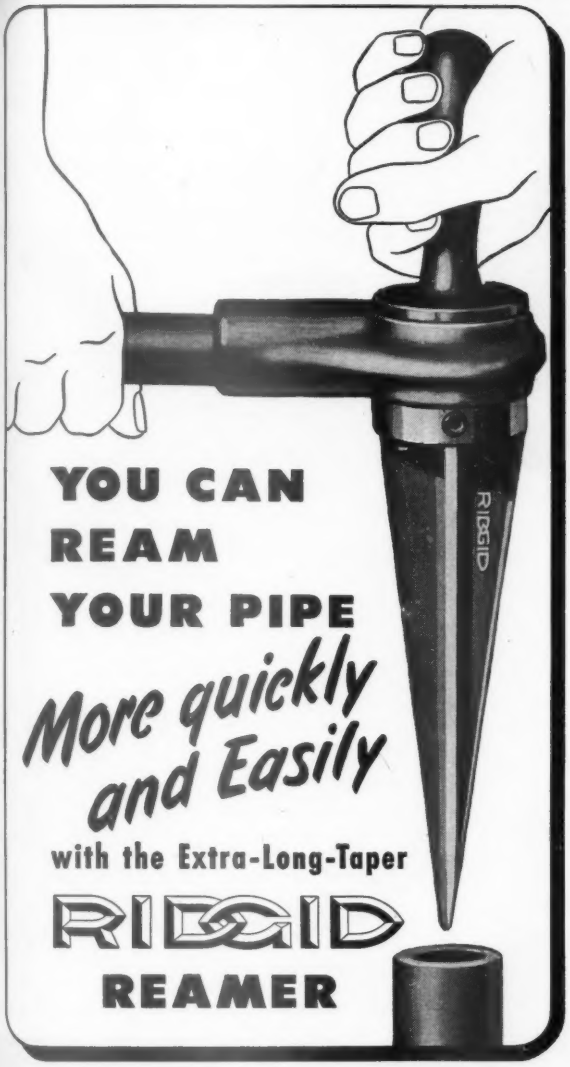


LOOK TO E.L.I. FOR:

SHOT HOLE DRILLS • SHOOTING TRUCKS • WATER TRUCKS
SUBSURFACE RECORDING PRESSURE AND TEMPERATURE GAUGES
DRILL BITS • DRILL PIPE • LABORATORY EQUIPMENT
STUFFING BOXES • SAMPLERS • THE PENETRON

Brochure on Request — Write for Catalogs

Engineering Laboratories, Inc.
CONSULTING ENGINEERS & MANUFACTURERS
602-624 East Fourth Street — Tulsa 3, Oklahoma, U. S. A.



YOU CAN REAM YOUR PIPE

More quickly and Easily

with the Extra-Long-Taper

RIDGID REAMER

It won't thin, flare or split pipe

● You ream the burr from any pipe in no time at all with a few easy feather-light ratcheted strokes of this RIDGID Reamer—and without damaging the pipe. The extra long taper of this unusual tool prevents thinning, splitting or flaring of pipe or conduit wall. It saves you time, work—and pipe! It comes complete with ratchet handle—or reamer unit alone fits your RIDGID 00R handle. Ask your Supply House for this handy RIDGID.

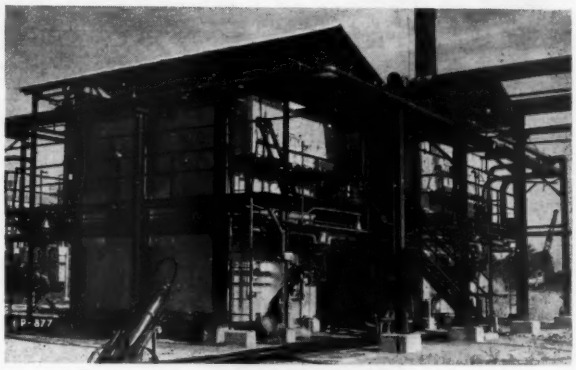
RIDGID

WORK-SAVER PIPE TOOLS

THE RIDGE TOOL COMPANY • ELYRIA, OHIO, U. S. A.

NATIONAL AIROIL FUEL OIL · GAS BURNERS

. . . burn *any* gas-liquid fuel . . . fire *any* furnace *and give* . . . *complete satisfaction*



National Airoil oil and gas burner units were selected by the British American Oil Company Ltd. to equip these modern furnaces in their new Furfural lubricating oil plant at Clarkson, Ont.

Backed by 33 years' extensive experience in the engineering and manufacture of fuel oil and gas burners, the National Airoil line has wide acceptance. Satisfied users both domestic and foreign, report entire satisfaction with National Airoil burners for *all* fuels including gas, oil, tars and sludges, in the successful firing of every type of furnace in petroleum refineries and chemical plants.

Put National Airoil burners to work for you. We have the right burner or combination of burners to do *your* combustion job. Our unbiased engineering advice is available . . . consult us about your problems.

Fig. P-635A

To burn safely and efficiently tars, pitches and asphalts, obtained directly from process, use the high pressure steam or atomizing type SAR.

Similar to the SAR, this SAL oil burner is adaptable in combination with powdered coal burners in large boilers.

2169

Send for complete information concerning these and other National Airoil burners.

NATIONAL AIROIL BURNER COMPANY, INCORPORATED

1236 East Sedgley Avenue

PHILADELPHIA 34, PENNA.

NATIONAL BURNER

Texas office: 2nd National Bank Bldg., Houston

OIL BURNERS • GAS BURNERS • GAS PILOTS • PUMP SETS
EXPLOSION DOORS • ACCESS DOORS • AIR DOORS
BURNER BLOCKS • FURNACE OBSERVATION WINDOWS

XUM

Dependable... Accurate ...VERSATILE GRAVITY METER

Weighing only 28 lbs. it can be carried on back pack - in small boat-in passenger car-on horseback

This North American Gravity Meter answers the need for a dependable, accurate meter which can be transported with ease and rapidity over all types of terrain . . . can be set up and readings made in a few minutes. In areas accessible by automobile, the Meter is mounted in the rear of a passenger car, and readings made in less than two minutes by extending the tripod through the car floor when the desired location is reached.

Actual field operations by unbiased operators as well as our own crews reveal an extremely high degree of accuracy. In one survey, a group of base stations checked within .01 of a milligal of the original values, established a year earlier by a different North American Gravity Meter. Many of these Meters have never required repairs or service throughout their long use in the field.

Manufactured in our own laboratories, the North American Gravity Meter is leased for domestic or foreign operation.

GRAVITY METER FIELD PARTIES ARE AVAILABLE FOR DOMESTIC AND FOREIGN SERVICE.

NORTH AMERICAN GEOPHYSICAL CO.

Gravity-Seismic Surveys *Geophysical Apparatus*

636 Bankers Mortgage Bldg. — Phone Charter 4-3523

HOUSTON 2, TEXAS

The decay of this substance results in the formation of a new element of atomic number 93, called neptunium ($_{93}Np^{239}$). Neptunium, in turn, emits another beta particle, becoming plutonium‡ ($_{94}Pu^{239}$), which emits an alpha particle, thus decaying to $_{92}U^{235}$, but so slowly that in effect it is a stable element.

Plutonium is fissionable with slow neutrons; hence is equivalent to U^{235} in this regard. By reference to Fig. 1, it is seen that plutonium might be expected to have similar chemical properties to osmium. On the contrary, it is now known that plutonium is more like uranium, and may be regarded as the second member of a new rare-earth series which begins with uranium. However, plutonium is sufficiently different from its progenitor, U^{239}, that it can be separated from uranium by chemical methods. The importance of this fact is made clear in a subsequent section.

Sources of Neutrons

At first it might appear that the only prerequisites for the release of atomic energy by fission are a source of neutrons and some uranium, thorium, or plutonium. Fundamentally, this is true. However, the amount of energy released by simply bombarding these elements with neutrons is far less than the energy required to produce the neutrons. Thus far nothing has been said concerning the sources of neutrons. These uncharged nuclear particles are produced either by fission or by the collision of nuclei at high velocities. There is a small neutron component in cosmic radiation, but much greater intensities are produced by bombarding certain light elements (for example, beryllium) with alpha particles, deuterons, or protons. Radon or radium mixed with beryllium provides a compact source of neutrons.§ It was by means of neutrons from such sources that fission was initially produced and studied. Deuterons or protons accelerated to a high velocity in a cyclotron can produce even more intense sources of neutrons.

However, enormously greater intensities are required to release significant amounts of atomic energy. As indicated in Equations 7 and 9, neutrons are released by the fission process itself. Under proper conditions, these secondary neutrons produce further fissions which release more neutrons to produce still more fissions, and so on. If the number of these self-induced fissions exceeds even by a minute amount the number produced by the initial neutrons, this avalanche-like reaction results. The propagation of the reaction is extraordinarily rapid. For this reason, unless carefully controlled, such reactions are violently explosive. If an explosion is desired, the initiation of the reaction, of course, must be delayed until the correct moment. The critical condition under which a self-sustained chain reaction occurs constitutes the crux of atomic energy as known today.

Critical Size

In the official U. S. Government publication, the now famous Smyth report,‖ this condition is summarized as follows: "The question of whether a chain reaction does or does not go depends on the result of a competition among four processes:

1. Escape of neutrons
2. Nonfission capture of neutrons
3. Nonfission capture by impurities
4. Fission capture

If the loss of neutrons by the first three processes is less than the surplus produced by the fourth, the chain reaction occurs; otherwise, it does not."

Two methods can be used to limit the escape of neutrons. The first is to enlarge the amount of active material to the point where the bulk of the neutrons produced is captured within the mass of the fissionable material itself. This procedure establishes a critical size above which the chain reaction takes place.* The second method of decreasing the loss of neutrons by escape is the use of a reflector surrounding the material. Heavy elements serve as reflectors of fast neutrons, for the relatively light neutron bounces off a heavy nucleus with very little change in speed. If reflection with a substantial decrease in velocity is desired, light-weight elements, called "moderators," are used.

The loss of neutrons by nonfission capture is equally important in determining the critical size. The likelihood that a given nucleus will capture a neutron is represented by a term, known as the "capture cross-section." This quantity is analogous to the area of the bull's-eye in a target. The capture cross-section not only varies enormously from element to element, but also from isotope to isotope, for a given element. In addition, as we have seen in the case of uranium, the capture cross-section is also strongly dependent upon the velocity of the neutrons. Certain elements, such as boron and cadmium, are very accessible to neutrons and behave like neutron sponges, because they so readily "soak up" neutrons. Most elements possess this characteristic to a considerably smaller degree. For example, nitrogen, iron, nickel, and vanadium have moderate capture cross-sections; whereas beryllium, magnesium, carbon, aluminum, zinc, tin, bismuth, and lead have very small capture cross-sections for neutrons. In establishing the critical size for the chain reaction, it is necessary that even minute traces of cadmium and boron be eliminated and that only traces of the medium cross-section elements be present. All essential structure materials must contain only elements with small capture cross-sections.

Because uranium and thorium ores are inevitably associated with elements of large or medium cross-section, a self-sustained reaction is impossible, regardless of the size of the ore deposit. In addition, because of the large proportion of U^{238} in ordinary uranium, the nonfission capture of neutrons by U^{238} predominates over the fission capture by U^{235} and U^{236}, even in a very large mass of this material. Hence, not only are uranium ores stable to fission, but even pure uranium metal does not undergo spontaneous fission in bulk. An important exception to this conclusion is discussed in the following section.

Production of Fissionable Materials

In the foregoing, thorium has been included with uranium as a source material. Because of the susceptibility of U^{235} to slow neutrons and the possibility of producing plutonium from U^{238}, the major effort of the Manhattan project centered on the direct or indirect use of uranium. No information has been released concerning chain reactions of thorium. Hence, this element will not be considered further, although thorium certainly constitutes a potential source of atomic energy.

A large part of the efforts of the project was devoted to the difficult task of separating the isotopes of uranium. U^{235} and U^{236} are essentially identical in chemical properties; hence, they are separable only by processes depending on the small

‡Neptunium (half-life 2.3 days) and plutonium (half-life about 20,000 years) do not occur in nature in any appreciable quantity. They lie beyond uranium in the periodic table (Fig. 1) and, hence, have been named for the planets Neptune and Pluto which lie beyond the planet Uranus.

§Such sources have recently been used for neutron logging of oil wells. A decrease in the intensity of back-scattered neutrons is indicative of the presence of light elements, notably hydrogen in the surrounding formations. This hydrogen is generally in the form of water, and the amount present is considered to be a measure of the porosity.

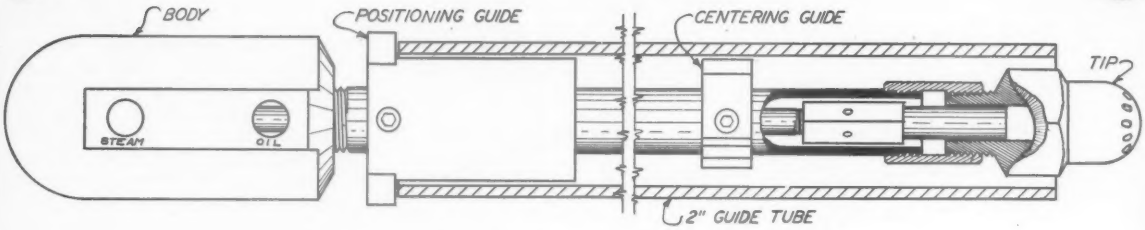
‖H. D. Smith, A General Account of the Development of Methods of Using Atomic Energy for Military Purposes under the Auspices of the United States Government 1940-1945, written at the request of Major General L. R. Groves, U. S. Army. Publication authorized as of Aug. 1945. Available from Princeton University Press, Princeton, N. J.

*The critical sizes for various materials are military secrets. Prior to the war it was estimated that a sphere of U^{235} 6 in. in diameter might be sufficient to sustain a chain reaction. This amount of U^{235} would weigh about 100 lb. The Smyth report implies that somewhat less than 100 kg is necessary.

XUM

JOHN ZINK BURNERS

Steamizer



Type MTB OIL BURNER

It's a fact — John Zink Oil Burners actually perform according to specifications.

— FEATURES —

1. **Gas or steam atomization of fuel oil or sludge.**
2. **Short flame at low excess air.**
3. **Low steam consumption.**
4. **Equal flow from all tip ports . . . uniform flame.**
5. **Vertical or horizontal firing.**
6. **Low fuel oil pressure required.**
7. **Gravity feed for moderate duty.**
8. **Easy to clean.**
9. **Extreme simplicity of design.**

John Zink Oil Guns burn any properly prepared commercial grade of fuel oil.

Write for descriptive literature.

JOHN ZINK COMPANY

TULSA, OKLAHOMA

NEW YORK . . . LOS ANGELES . . . DETROIT . . . SALT LAKE CITY . . . HOUSTON

(1.3 per cent) difference in atomic weight.

Four large-scale physical methods have been used to produce U^{235} for atomic bombs (see Fig. 4). Several other methods offer promise, but have not progressed beyond the laboratory stage.

The rate of diffusion of a gas through an ideal porous barrier is inversely proportional to the square root of its molecular weight; hence, molecules containing U^{235} diffuse slightly faster than similar molecules containing U^{238}. To obtain a practical degree of separation, a large number of successive stages, known as a "cascade," must be used. In certain aspects the procedure is analogous to the separation of closely boiling liquids by fractionation, the number of theoretical plates in a fractionating column being similar to the number of stages in a cascade. However, the arrangement of stages is more complicated and the amount of recycling is much greater in the diffusion process. For an actual uranium-separation plant, it may be necessary to force through the barriers of the stage 100,000 times the volume of gas that comes out of the top of the cascade. Another complication is that uranium hexafluoride, the likely process compound, is highly reactive and corrosive at the temperature of vaporization. The final plant at Clinton Engineer Works in Tennessee, put in successful operation early in 1945, contained acres of barrier and thousands of pumps. It represents an achievement comparable in magnitude to the large-scale production of 100-octane gasoline or of synthetic rubber.

The application of pseudogravitational forces of large magnitude produced in high-speed, cylindrical centrifuges has been used successfully for the enrichment of U^{235} in a gaseous mixture. The radial force field of the centrifuge acts more strongly on the heavy molecules than on the light ones. Hence, the concentration of U^{235} near the axis is slightly greater than in the peripheral region. This method offers the advantage of depending directly on the difference in molecular weights, not on the square root of the ratio as in diffusion methods.

In the thermal-diffusion plant a liquid compound of uranium circulates by convection between two coaxial cylinders maintained at different temperatures. Depending upon both the molecular weights and on the intermolecular forces, there is a tendency for one type of molecule (for example, those containing U^{235}) to concentrate in the warm region and the other in the cold region. A large-scale thermal-diffusion plant operating on this principle was built at Clinton Engineering Works. The amount of heat required to operate this plant is sufficient to supply the energy requirements of a fair-sized city. The output of uranium enriched in U^{235} is used as feed stock for the electromagnetic method which produces a much more complete separation.

Although a late starter in the race to separate the isotopes of uranium, an electromagnetic separator called a "calutron" produced the first appreciable-sized samples of pure U^{235}. The principle involved is identical with that of the mass spectrographs now finding application in the petroleum industry for the analysis of mixtures of gaseous hydrocarbons. Molecular ion beams are produced by bombarding gaseous uranium compounds with electrons and accelerating the resulting charged particles to a high velocity in an electric field. The ion beam is then split into two parts by passage through an intense magnetic field. The heavier U^{238} molecules move in a larger circle than the lighter U^{235} molecules, as shown schematically on the right in Fig. 4. A number of very difficult problems were overcome before a practical unit was achieved. The separation plant finally constructed consists of a veritable city of calutrons.

While these developments in the separation of uranium isotopes were taking place, another compartment of the Manhattan project was studying methods of producing plutonium. A most ingenious process was evolved which not only yields large amounts of this fissionable material, but appears as the most likely industrial source of atomic energy. It is in the production and utilization of plutonium that petroleum may find an atomic competitor.

The major steps involved in the production of plutonium are shown schematically in Fig. 5. The crude source material is pitchblende, carnotite, or some other uranium mineral. After mining and milling, the ore is concentrated and treated chemically to obtain the pure oxide, U_3O_8. The next step requires the preparation of essentially spectroscopically pure uranium metal. This very exacting metallurgical work requires considerable know-how, as do all of the other specialized techniques which have been so expeditiously developed under the Manhattan project. The metal, of course, contains the same proportion of isotopes as the original ore: viz., 99.3 per cent U^{238} and 0.7 per cent U^{235}. It is cast into bars, and is coated

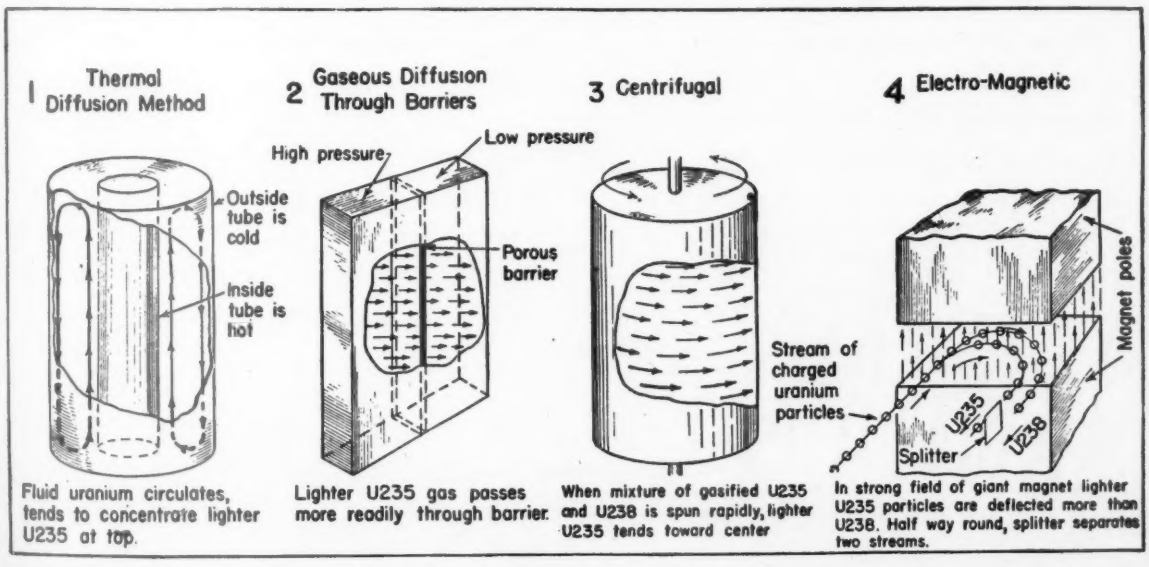

1 Thermal Diffusion Method
2 Gaseous Diffusion Through Barriers
3 Centrifugal
4 Electro-Magnetic
High pressure
Low pressure
Outside tube is cold
Inside tube is hot
Porous barrier
Stream of charged uranium particles
Magnet poles
U235
U238
Splitter
Fluid uranium circulates, tends to concentrate lighter U235 at top.
Lighter U235 gas passes more readily through barrier.
When mixture of gasified U235 and U238 is spun rapidly, lighter U235 tends toward center
In strong field of giant magnet lighter U235 particles are deflected more than U238. Half way round, splitter separates two streams.

Fig. 4—The four most successful methods of separating the isotopes of uranium. These diagrams merely illustrate the fundamental principles involved. In each case, the apparatus is intricate, and a multiplicity of units is required to achieve a useful amount of separation

XUM

Now!

G·MV

COMPACTNESS
RELIABILITY
VERSATILITY
ECONOMY

in the smaller

G·MX

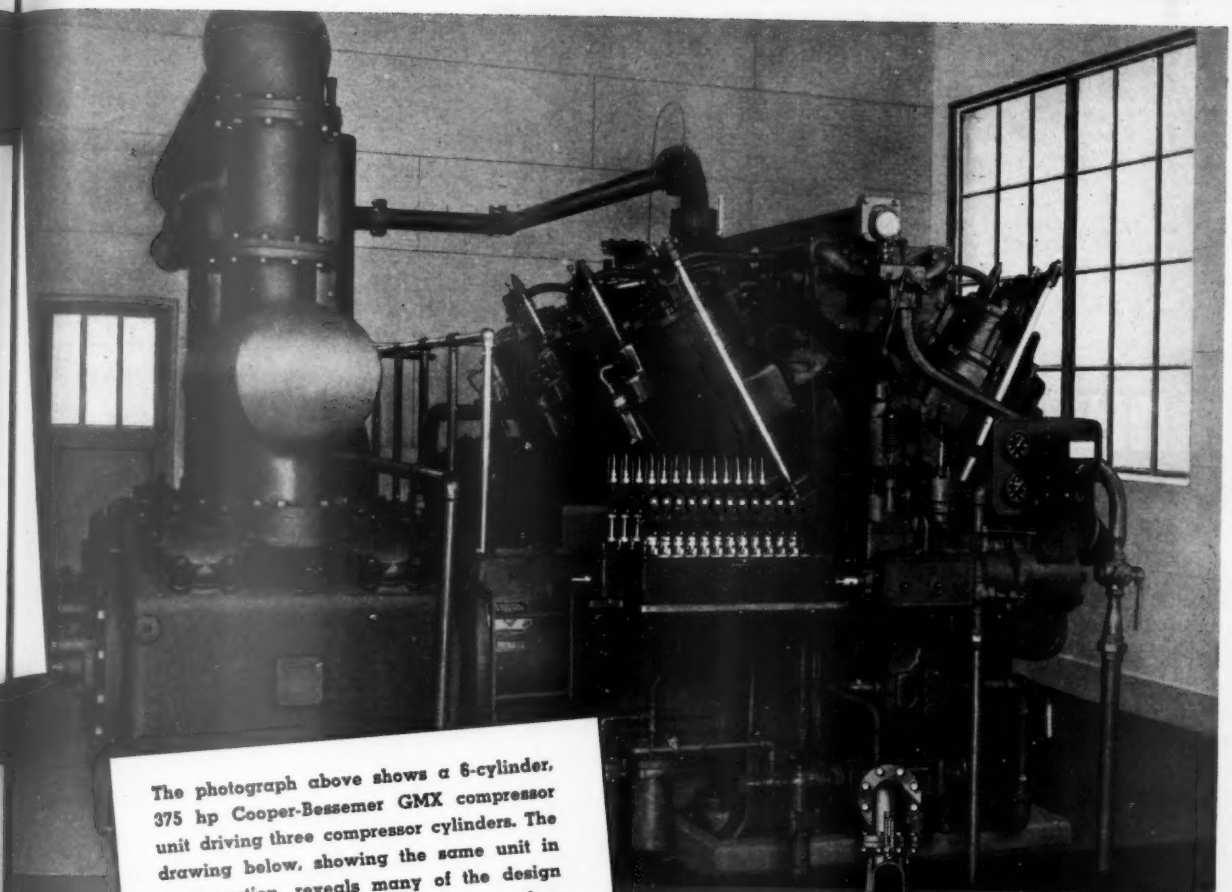
Cooper-Bessemer's highly successful V-angle, 2-cycle compressor units are now built in two power cylinder sizes: Type GMX from 250 to 625 hp; Type GMV from 400 to 1000 hp. Both are built in 4, 6, 8, and 10 cylinder sizes rated 62½ and 100 hp per cylinder respectively.

Repeatedly, in hundreds of outstanding installations, the GMV has demonstrated the value of its modern design and its many advanced features. Now, without exception, all these advantages are available in the smaller GMX for those compressor jobs requiring less power but all the stamina, on-stream reliability, and operating economy for which the GMV is noted.

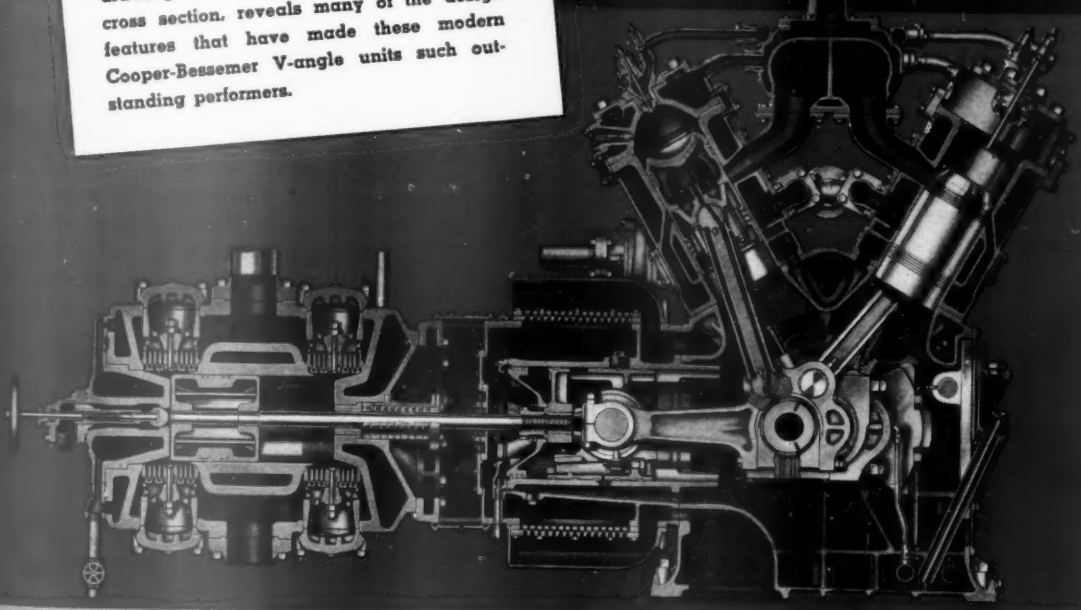
The nearest Cooper-Bessemer office is always ready to cooperate with you or your engineers in investigating and planning the ideal compressor set-up for your present or future needs.

TYPE G·MV & G·MX **Compressors**

New York · Washington · Bradford, Pa. · Parkersburg, W. Va. · San Francisco, Cal. · Seattle, Wash. · Houston



The photograph above shows a 6-cylinder, 375 hp Cooper-Bessemer GMX compressor unit driving three compressor cylinders. The drawing below, showing the same unit in cross section, reveals many of the design features that have made these modern Cooper-Bessemer V-angle units such outstanding performers.



by **Cooper-Bessemer**

MOUNT VERNON, OHIO AND GROVE CITY, PENNA.

Houston, Dallas, Greggton, Pampa and Odessa, Texas Tulsa Shreveport St. Louis Los Angeles

SAVE FUEL . . .

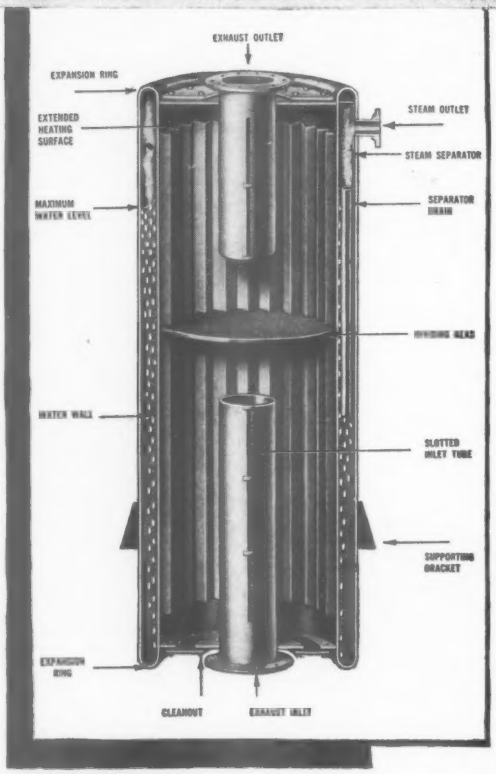
PUT EXHAUST HEAT TO WORK WITH

MAXIM HEAT RECOVERY SILENCERS !

There are few industrial plants that would knowingly throw away fuel, and yet many do just that when they allow engine exhaust heat to escape without making use of it. Maxim Heat Recovery Silencers utilize exhaust heat to produce steam or hot water for heating or processing operations. They combine in one unit effective silencing of exhaust noise, spark arresting (where necessary) and efficient heat recovery.

From an efficiency point of view, the value of using Maxim Heat Recovery Silencers is obvious. Engine exhaust must be silenced as a matter of good public relations. The use of Heat Recovery Silencers accomplishes this and, in addition, produces "fuel-free" steam or hot water.

For silencing without the heat recovery feature, Maxim makes silencers for internal combustion engine exhaust or intake, steam engine exhaust, air compressor intake, vacuum pump discharge, blower intake and discharge, high velocity steam, air or gas discharge. Engine exhaust silencers available with or without spark arrestor. Bulletins on request.



Write for Bulletin

Bulletin WH-101 is an eight page illustrated folder showing various types of heat recovery silencers and also practical working hook-ups. A copy will be sent promptly on request.

THE MAXIM SILENCER COMPANY • **98 HOMESTEAD AVE., HARTFORD, CONN.**

ARMY E NAVY

MAXIM

with a thin impervious layer of very pure aluminum to protect the uranium from direct contact with the cooling water. This "canned" uranium is then placed in a lattice structure made of highly purified graphite. The size of this so-called pile is very precisely determined. It contains just slightly more uranium than the critical amount required to maintain a chain reaction. A simplified explanation of the operation of the pile is as follows:

When the pile has been assembled to the proper size, it is triggered by stray neutrons from cosmic radiation. These produce a few fissions of either U^{235} or U^{238}, depending on whether these initiating neutrons are slow or fast. The secondary neutrons resulting from the fissions are fast and, hence, cannot produce additional fissions in U^{235}, although they may cause fissions in U^{238}. The most probable result, however, is that these secondary neutrons will be slowed down by collisions to intermediate velocities before producing such fissions. Because of the predominance of U^{238}, most of these neutrons are captured to form U^{239}. However, by having pure carbon in the form of graphite alternating with the uranium, many of the secondary neutrons are slowed down to thermal velocities. Because the capture of neutrons by U^{235} increases inversely with the velocity of the neutrons, the probability of producing fissions in U^{235} is greatly increased by the use of the graphite moderator. In this way a self-sustained chain reaction is produced.

The neutron flux increases to a very high intensity, enormously greater than all of the cyclotrons in the world combined. Several factors limit the extent of this effect. The large amount of energy released by fission results in considerable heating of the pile which, in turn, causes thermal expansion. The predetermined size has been so precisely established that even a small rise in temperature increases the surface and provides an important limiting effect on the spontaneous action of the pile. In addition, alloy rods high in boron or cadmium are arranged for movement in and out of the pile for vernier control. These rods soak up the neutrons because of their large capture cross-section.

Of course, a large amount of cooling must be provided in order to limit the rise in temperature. Special pipes, made of elements with small capture cross-sections, provide channels for the cooling water. The magnitude of this cooling problem can be appreciated from the fact that an appreciable rise in temperature of the Columbia River takes place when one of the piles is operating at the Hanford plant in Washington. The production of a pound of plutonium per day releases energy in the form of heat at the rate of about 1,000,000 kw.

When the pile reaches equilibrium, there is steady fission of U^{235} and, to a lesser extent, of U^{238}. The constant flood of neutrons within the pile produces a continuous transmutation of U^{238} through its successive steps to plutonium. At the same time that the amount of plutonium in the uranium is gradually building up, there is a parallel increase in the fission products. These elements of medium atomic weight capture neutrons and, after a certain period of time, the concentration of fission

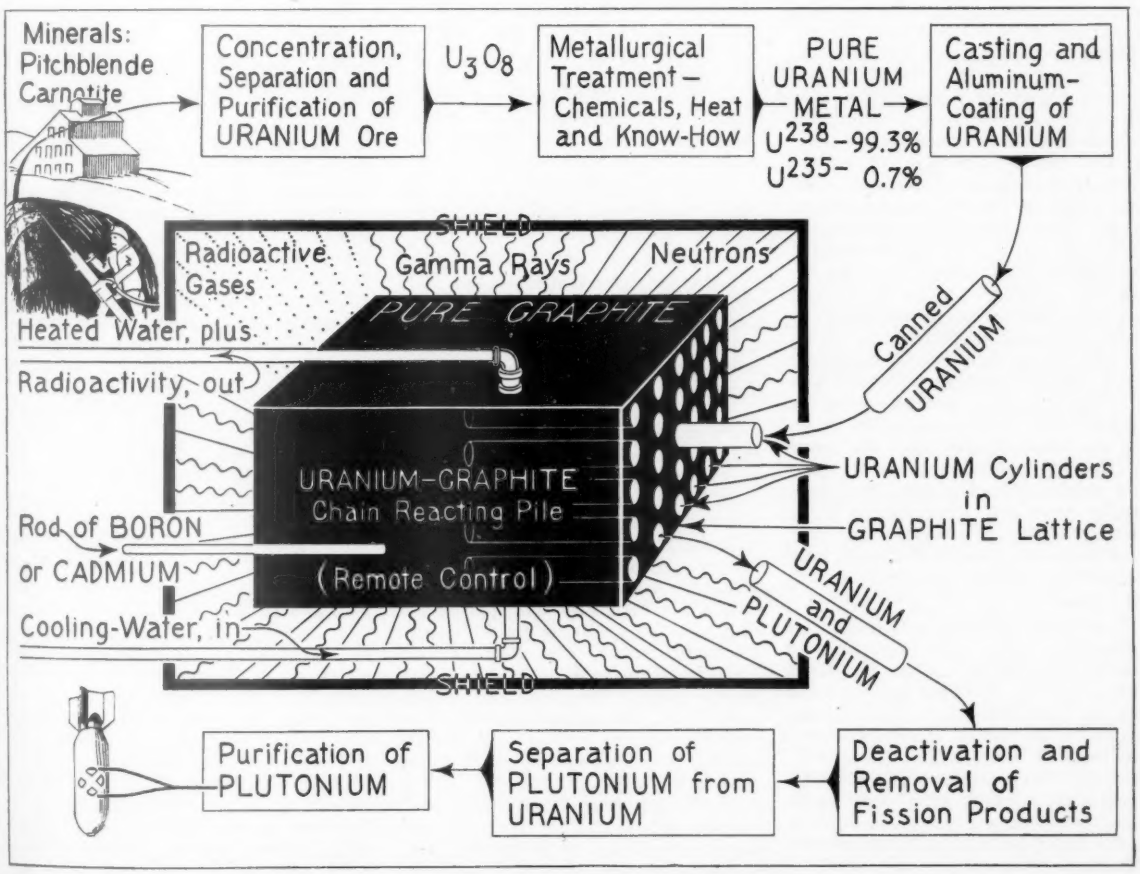


Fig. 5—The production of plutonium. Pure uranium prepared by the successive steps indicated above is coated with pure aluminum and introduced into the chain-reacting pile, represented schematically in the center. Cylinders of uranium containing plutonium and fission products are removed at intervals from the pile and purified to form plutonium suitable for use as the active ingredient in atomic bombs or in compact sources of atomic energy. The heat now removed by the cooling water may find future industrial application

XUM

products rises to a point where an appreciable decrease in efficiency of the pile results. At some optimum concentration of plutonium, the bars of uranium containing plutonium and fission products are removed. The pile and its products are intensely radioactive and, hence, extremely dangerous to personnel. For this reason the operation of the pile and chemical treatment of the uranium, after removal from the pile, must be carried on by remote control within air-tight concrete shields several feet in thickness. Following removal of the fission products, the relatively small amount of plutonium is separated from the bulk of the parent uranium, after which the plutonium is purified. This material is then ready for incorporation in an atomic bomb.

Utilization of Atomic Energy

The successful development of large-scale sources of atomic energy was carried out under the compelling stimulus of war. Hence, military applications have preceded peacetime utilization. The construction of atomic bombs is naturally not public information. However, from the foregoing fundamental principles, it is evident that the explosive material in an atomic bomb consists of separate pieces of U^{235}, plutonium, or other fissionable substance—each of which is below the critical size. Detonation occurs practically instantaneously when the parts of the bomb are suddenly combined into a compact super-critical mass. The explosion produces an extremely rapid rise in temperature, the particles in violent motion being the nuclear fission fragments. All immediately surrounding materials are made incandescent, thereby producing a blinding flash, far more intense than the sun itself. The surrounding air is heated to such a degree that a fiery sphere of glowing gas rises rapidly from the scene of the explosion, and vents itself and practically all of the active materials into the stratosphere. The accompanying pressure wave and heat radiation devastate essentially everything within a radius of several miles.

From both military and industrial points of view, it is important to realize that there are no pea-sized atomic bombs. Nothing less than the critical size will work. Hence, the explosion is one of Hiroshima proportions, or none at all. It is evident that these super-explosives will necessitate revolutionary changes in modern warfare. Even more evident is the need for international understanding.

However, the purpose of the present discussion is to consider the possible effects of atomic energy on the petroleum industry, not on military strategy. The fission reaction releases about 32 billion B.t.u. per pound of U^{235} or plutonium, and the radioactive decay of the fission products releases an additional 8 billion B.t.u. This energy is more than a million times the heat of combustion of a good grade of coal (14,000 B.t.u. per pound) or of 100-octane gasoline (22,000 B.t.u. per pound). Yet the enormous amount of heat produced in the present piles is wasted. By means of heat exchangers, it probably would be relatively simple to use some of this energy for household or other low-temperature heating. For obvious reasons, few if any houses or factories are located near these piles. In order to utilize such heat for industrial purposes, it would be necessary to operate the pile at temperatures comparable to those of modern steam power plants. Apparently, the problems involved in this transition are very large. Smyth has summed them up in the statement that "the technological gap between producing a controlled chain reaction and using it as a large-scale power plant is comparable to the gap between the discovery of fire and the manufacture of a steam locomotive." Those intimately acquainted with the operation of the piles probably know many limiting factors. The following are among the more obvious ones:

a. The capture of neutrons by U^{238} would decrease because of the increase in velocity with rise in temperature.

b. The corrosion of aluminum and other metal parts probably increases rapidly with temperature.

c. Shutdowns are very serious; yet the pile must operate not only by remote control, but also without maintenance or repair. Operation at higher temperatures would undoubtedly increase the number of shutdowns.

d. The thermal conductivity of uranium and graphite may impose major restrictions on the practicable temperatures.

If developments in this field are allowed to flourish unhampered by military restrictions and government controls, it seems probable that these problems can be solved in a reasonably short time, and that atomic energy will be available for industrial purposes within the next decade. The question will then be: Can atomic power compete with petroleum, coal, and water power on an economic basis? Too many unknowns are involved to allow other than speculation, but in all likelihood the answer will not be clearcut.

Inasmuch as coal is the most economical fuel for large installations, it would appear that natural uranium piles may compete with coal, particularly in the generation of electric power. The piles could be located near the populated areas, but sufficiently remote to prevent radiation hazards. The heat released would be used to produce steam to drive turboelectric generators. This electric power would actually be a byproduct from the production of plutonium and radioactive fission materials and the treatment of substances by radiation. As in all of these speculations, the economics depend upon the demands for and the restrictions on the use of fissionable materials. Some of the heat from these large piles also might be used to operate thermal or diffusion plants for separating U^{235} from uranium.

The natural uranium and graphite piles, which may compete with coal, are far too bulky to be used in units for mobile power. By using uranium that has been enriched in U^{235}, or to which plutonium has been added, the size of the pile can be considerably reduced. The use of heavy water (deuterium oxide) as a moderator in place of graphite also allows substantial reduction in size. Although heavy water is more expensive and difficult to obtain than graphite, piles containing this liquid moderator have been built at Chalk River, Ontario, and at the Argonne site near Chicago.

With the decrease in size of power units, the competition with petroleum would probably begin in replacing fuel oil in large transports and naval vessels. Full speed ahead would be achieved by pulling out the cadmium "throttle." A distinct advantage for naval vessels would be that "refueling" would be infrequent. An additional consideration would be that the atomic fuel is nonflammable. Shielding would be a major problem, and would add considerably to the weight and size of the units. Such applications of atomic energy might be entirely ruled out on this basis alone.

Pure U^{235} and plutonium in excess of the critical sizes can be assembled—provided cadmium, boron, or some other neutron absorber is present in sufficient amount to prevent the chain reaction. If the absorber were gradually removed until the critical point is reached, a controlled release of energy from a very compact source might be possible. However, with pure U^{235} or plutonium, this procedure would be extremely sensitive—a slight movement of the absorber might result in a violent explosion. For this reason, compact units will probably use a mixture of U^{235} and U^{238}, containing not more than about 20 per cent of the lighter isotope and some moderator in order to obtain a safe degree of controllability. Even more problems than arise with the larger units must be solved before diminutive atomic engines will be possible. For military purposes such engines might supply the power for guided missiles or robot planes. In order to compete

You Can Always "Bank On"

The OIL BANK OF AMERICA

Universally recognized as *The Oil Bank of America*, the National Bank of Tulsa has always provided complete banking service to the Oil Industry.

Many years of experience have given its officers the knowledge and understanding that make possible our specialized services that are so helpful to individual operators and producing companies.

NATIONAL BANK OF TULSA

The Oil Bank of America

Member Federal Deposit Insurance Corporation

XUM

Braun Shell-Design Kinematic Viscometer Bath

Braun Shell-Design

KINEMATIC VISCOMETER BATH

Gives Highly Accurate Measurement

This apparatus has been designed to meet the need for a constant temperature bath, operating to closely controlled limits, for the exacting work of making kinematic viscosity measurements of the highest accuracy. Viscosity determinations can be made with greater speed, convenience and accuracy than is possible by other methods.

This bath will accommodate nine Zeitfuchs Viscometer Tubes simultaneously, permitting continuous operation. It is suitable for kinematic viscosity measurements of all oils. Operation of the apparatus, including cleaning of tubes, is simplicity itself.

The Braun Shell-Design Kinematic Viscometer Bath has a sensitive and precise electronic regulator for absolute control of temperature to within .015° F. Continuously variable settings can be made at any point between room temperature and 240° F.

WRITE FOR BULLETIN

BULLETIN C-144 GIVES COMPLETE DESCRIPTIVE DETAILS. ADDRESS DEPT. O-11 FOR YOUR COPY.

BRAUN CORPORATION

2260 EAST 15TH ST., LOS ANGELES, CALIF.

BRAUN-KNECHT-HEIMANN-CO. San Francisco, California

BRAUN

SCIENTIFIC SUPPLIES CO. Seattle, Washington

MALLEABLE IRON CASTINGS

The physical properties of Iowa Malleable Castings consistently exceed the maximum specifications of all accepted testing sources. This means malleable parts of greater shock resistant qualities . . . of superior strength and ductility. With modern foundry and laboratory facilities we are in a position to serve the oil equipment and allied industries with uniformly dependable malleable iron castings. Inquiries are invited on your requirements.

IOWA MALLEABLE IRON COMPANY

542 Heflin Street Fairfield, Iowa

GASOLINE DEEP-ROCK MOTOR OILS

Looking Forward with the Petroleum Industry

DEEP ROCK OIL CORPORATION

TULSA, OKLAHOMA

seriously with diesel oil and gasoline, atomic engines must be adaptable to trains, trucks, planes, and automobiles. For these purposes the shielding problem would be most acute. The compactness gained in using atomic fuel might be more than offset by the large amount of shielding required. Of course, all of these considerations have been limited to the source of atomic energy now known; i.e., to nuclear fission of heavy elements. It will be recalled that the consolidation of light elements into medium-weight elements releases comparable amounts of energy. Although such nuclear syntheses have never been accomplished on a large scale, they have been achieved in minute amounts in the laboratory. If future research extends the range of available atomic energy to include the light elements, many of the foregoing limitations may be removed. In addition, these light elements would probably be far more plentiful than the relatively scarce fissionable elements, uranium and thorium.

Within the bounds of available information, it would appear that petroleum and coal will probably continue for at least another generation as the primary sources of energy for transportation and heating. Water power and coal will probably generate most of the electricity during the next 50 years. Although atomic energy may gradually enter as a competitor, its most extensive applications will probably be in new fields of human endeavor. Industrial processes at extremely high temperatures, ultra-high-speed transportation, the production of radioactive materials for industrial and medical purposes as well as for some scientific investigation, the manufacture of rare elements by transmutation, and the treatment of materials by radiation are among the more likely specialized uses of fission energy in addition to the continued production of atomic explosives.

For some time the more conservative members of the petroleum industry have been concerned about what the world would use for fuel when the petroleum and coal reserves were exhausted. Prior to 1935 new discoveries more than offset the increased consumption of petroleum. During the past 10 years the discovery rate has rapidly declined while production has soared. Although there will be a postwar respite, this trend is likely to continue for some time. However, the petroleum industry now has somewhat less occasion to regret the expenditure of a large part of the earth's supply of chemical energy. By the time this source is exhausted, there should be plenty of atomic energy available.

Although this change seems inev-

Air Express speeds the day she'll listen to HER NEW RADIO

Yes, as industry races against time to make more and more radios, irons, washing machines and other goods the public wants and needs, Air Express is helping to get them faster.

Here's how. When a plant makes production changes, new tools, dies, machinery and parts are needed *fast*—critical material that is obtained via Air Express in a matter of hours. With such delivery speed, industry as a whole is gaining millions of man-hours in getting consumer goods back on the market and into the home.

Specify Air Express-a Good Business Buy

When time means man-hours saved, production gained, a customer made — Air Express "earns its weight in gold" as thousands of firms, large and small, have learned.

Shipments travel at a speed of three miles a minute between principal U. S. towns and cities, with cost including special pick-up and delivery. Same-day delivery between many airport towns and cities. Rapid air-rail service to 23,000 off-airline points in the United States. Service direct by air to and from scores of foreign countries.

TYPICAL RATE CHART

AIR MILES	2 lbs.	5 lbs.	25 lbs.	40 lbs.	Over 40 lbs. Cents per lb.
149	$1.00	$1.00	$1.00	$1.40	3.5
349	1.04	1.25	2.63	4.20	10.5
549	1.11	1.53	4.38	7.00	17.5
1049	1.36	2.19	8.75	14.00	35.
2349	1.65	4.03	20.13	32.20	80.5
Over 2350	1.68	4.20	21.00	33.60	84.

AIR EXPRESS

GETS THERE FIRST

Write today for "Jig Saw Puzzle," a booklet packed with facts that will help you solve many a shipping problem. Air Express Division, Railway Express Agency, 230 Park Avenue, New York 17. Or ask for it at any Airline or Express office.

Phone AIR EXPRESS DIVISION, RAILWAY EXPRESS AGENCY Representing the AIRLINES of the United States

An object lesson in

FIRE DESTRUCTION

...LOSS $50,000

● When an unprotected oil filled transformer caught fire, burning oil showered the overhead structure and an intense blaze developed. Leaking oil from the transformer fed the flames; and insulators, bushings and surrounding steelwork were severely damaged. The estimated loss was $50,000.

Regrettable, of course. Yet losses such as this can be avoided. An "Automatic" FIRE-FOG System would have quickly snuffed out this blaze with little or no fire damage. Automatic in operation and super-sensitive to sudden, abnormal heat rises, FIRE-FOG goes into action instantly—and seconds later, a blaze which might well have been ruinous, is extinct.

Wartime's unremitting demands have proven the safe, dependable protection offered by "Automatic" FIRE-FOG. The opportunity to assist in planning definite fire protection for *you*, will be welcomed.

"Automatic" Sprinkler

"AUTOMATIC" SPRINKLER CORPORATION OF AMERICA

YOUNGSTOWN, OHIO . . . . . OFFICES IN 36 CITIES

"Automatic" Sprinkler manufactures and installs a complete line of fire protection devices and systems for all types of fire hazards. Listed by Underwriters' Laboratories, Inc., and approved by Factory Mutual Laboratories.

itable, it will certainly not be rapid. Few of us will live to drive atomic automobiles or fly jet planes powered by nuclear energy. When this time arrives, there will still be a petroleum industry, but it may have changed rather remarkably in character. Instead of petroleum being primarily used for fuel, it will be the raw material for all kinds of organic substances.

Already it sometimes seems a waste to burn hydrocarbon molecules when they can be converted into valuable compounds like synthetic rubber, toluol, polymerized lubricants, plastics, and medicinal substances. The war has emphasized the importance of petroleum as a source substance in organic synthesis. An increase in the availability of atomic energy, together with an increase in the knowledge of the organic chemistry of petroleum, should result in considerable expansion of the chemical utilization of petroleum. The refinery of the future will be more of a chemical factory than a producer of fuel.

Acknowledgment

The author wishes to express his appreciation of the helpful suggestions of his colleagues R. D. Evans, M. S. Livingston, W. J. Mead, F. K. Morris, and W. L. Whitehead. Fig. 1 was prepared from a similar table compiled by J. W. Irvine, Jr. Fig. 4 appeared in a special article in most of the September scientific publications of McGraw-Hill Publishing Co., and is reproduced with the permission of this company. Fig. 5 is the scientific handicraft of F. K. Morris.

Million-Volt X-ray Apparatus Has Industry Potentialities

Capable of revealing subsurface flaws in metallic construction materials in about one-six-hundredth of the time of that required by prewar units, the 1-million-volt X-ray apparatus developed under military necessity will find wide uses in industry, according to Albert M. Orme, of War Production Board.

Cited in a recent announcement by the Safety and Technical Equipment Division of WPB, of which Orme is acting director, the value of the million-volt X-ray unit is immediately apparent in safety and cost of labor to builders of heavy products. It is claimed that the 1-million-volt apparatus has almost the flexibility of a one-man dental unit, is shockproof, and much smaller than its before-the-war predecessor. As an example of its speed in examining welded seams in steel, the announcement states that in less than a minute the unit can detect imperfect welds in 2-in. ship plates.

Behavior of Water-Input Wells

(Continued from page 216)

ly above the weight of the overburden above the packer at the top of the sand. At higher pressures the slope of the line sometimes increases because the rupture of the formations; this phenomenon is discussed in Section 7. The slope of the line is the localized injectivity index; i.e. $\frac{\text{change in intake rate}}{\text{change in pressure}}$. In taking tests in the manner described previously herein, it is found that the shut-in pressure immediately before starting the test is the x intercept of the pressure-input curve; i.e., the pressure at which the well neither takes nor discharges water.

When the pressure on the well head is suddenly increased, the intake rate increases very greatly; and, as the new gradient becomes established, the rate falls rapidly at first and then more slowly. This is illustrated in Fig. 8 which shows the instantaneous changes in intake rate (measured with a recording orifice meter) with pressure, when the pressure was increased stepwise in equal increments. The rate during the first few seconds was too large to measure. The rates at the end of the first minute at the new pressure were always substantially higher than the rates at the end of the second minute or the fifth minute. However, the changes in intake rate at the end of any given period per unit change in pressure were substantially the same. This is shown in Fig. 9, which shows the rates at the end of the first minute and also the rates at the end of the second and the fifth minute, plotted against the corresponding pressures. The slope of these lines is the change in rate per pound per square inch change in pressure, which is the localized injectivity index. As the three curves have essentially the same slope, it may be seen that the localized injectivity index can be reliably determined in spite of the rapid variation in absolute intake rates.

A few days after the test shown in Fig. 8, the well was treated with acid, during the course of which treatment it was back-flowed, shut in for 6 days and flushed out, during which time it was back-flowed again. The first day after the application of pressure, the well was taking water at the rate of 150 bbl. per day, which was five times its normal intake rate. A localized injectivity-index test was run (Fig. 9) which showed no change in slope, indicating that the greatly increased intake rate was ascribable solely to the decrease in reservoir pressure—resulting from the back-flowing and shut-in period, and not to any beneficial effect of the acid. This deduction was confirmed 6 days later when the intake rate had decreased to its previous rate of 30 bbl. per day. Although good results were not obtained in the case of this well, acid treatment has resulted in great improvement in the intake rate of old wells.

The intake rate at different pressures might be determined after longer periods of time, so that equilibrium conditions throughout the reservoir were established between tests. The slope of the curve would then indicate: not the localized injectivity (or conductivity of the immediate vicinity) of the input well alone, as defined previously, but, rather, the conductivity of the whole system surrounding the well—which is substantially affected by the productivity indices of the adjoining producing wells. This pattern conductivity is the equivalent of the injectivity index as defined in Section 4-a herein. A curve of intake

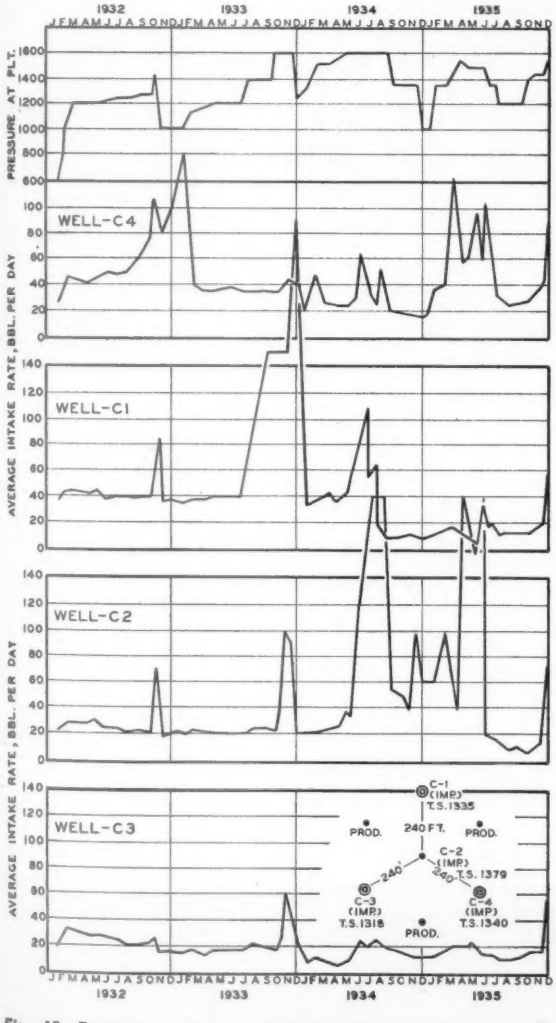


Fig. 19—Pressure and input histories of four adjacent wells (Bradford, Pa.) showing breakthroughs occurring at different pressures

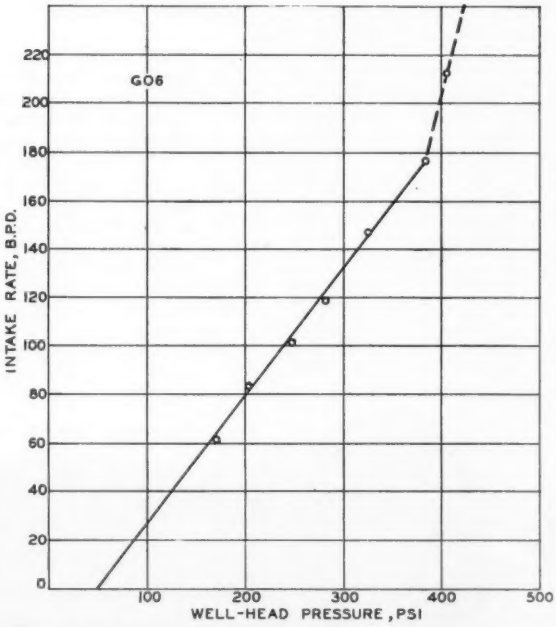


Fig. 20—Pressure-input test of Well G06 (Siggins, Ill.)

Preferred by the *"Man on the Job"!*

OTHER McKAY MILD STEEL ELECTRODES

McKay Grade	A.W.S. No.
No. 21	E4510
No. 3	E4520
No. 15	E6010
No. 17	E6012
No. 116	E6012
No. 16	E6020
No. 18	E6030
No. 16-H	None
No. 117	None
No. 19	None
No. 10	None
No. 713	E7010
No. 711	E7011
No. 713	None
No. 716	E7020

Because McKAY No. 14 is the *one* electrode which meets most welding rod requirements for maintenance, repair and operating—it has been popularly called the MRO Electrode by the man on the job.

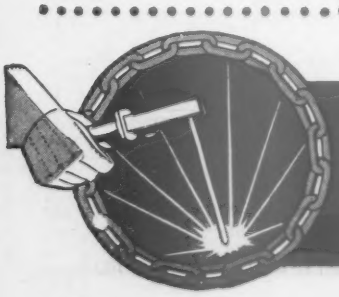
The McKAY No. 14 Electrode is particularly suitable for factory maintenance. It operates with equal ease on either AC or DC machines. Even a relatively inexperienced welder does not have difficulty in getting excellent results.

But whether you require this mild steel electrode or any other of the wide range of mild steel, alloy steel and stainless steel electrodes—specify McKAY by name. The complete uniformity and successful performance of McKAY Rods under all work-uses make McKAY Welding Electrodes preferred by the "man on the job" as well as by the men who engineer the jobs.

Specifications:

McKAY No. 14 Mild Steel Electrode—Made to conform to the standards of American Welding Society's E1613 type of electrode. Made in sizes 1/16", 5/64", 3/32", 1/8", 5/32", 3/16", 7/32", 1/4" and 5/16".

GENERAL SALES OFFICES: YORK, PA.



THE McKAY COMPANY
PITTSBURGH, PA.
WELDING ELECTRODES . . . COMMERCIAL CHAINS . . . TIRE CHAINS

rate vs. pressure taken in this manner would be flatter (because of the lower conductivity); and the x intercept, i.e., the pressure at which the well takes no water, would be the static reservoir pressure of the formation.

Fig. 10 compares the slopes of the "intake rate vs. pressure" curves taken at short intervals (10 minutes) and longer intervals (24 hours) on the same well. It will be seen that the slope at the longer intervals is flatter, and the x intercept is about 250 psi. sand-face pressure. The average reservoir pressure is not known, but it is probably not very different from this pressure.

d. Mathematical expression of localized injectivity index.—After the well has been shut in and the pressures equalized in the neighborhood of the well, it then behaves (on resuming water injection) as a single well until the outer limit (r_e) of the new pressure gradient encroaches on the area where the pressures are not equalized. It, therefore, starts out taking water at a high rate, like a new well—except that, because the gas space to fill up is very small, the radius (r_e) encroaches more rapidly, and a condition of interference is reached in a matter of a few hours. Therefore, the single-well flow formula is applicable for a limited period of time.

The intake rate Q is given by:

$$Q = \frac{2\pi k h (p_w - p_i)}{\mu \log_e r_i/r_w} \qquad (9)$$

In this expression p_i is the transient back pressure and r_i is the distance out from the well to which the pressures are equalized at the value p_i.

Differentiating, the localized injectivity index, which is the change in intake rate with changes in pressure (p_i being constant), will be:

$$\frac{dQ}{dp_w} = \frac{2\pi k h}{\mu} \left(\frac{1}{\log_e r_i/r_w}\right) \qquad (10)$$

Experimentally, it has been found that, for small volumes of water injected, dQ/dp_w is constant, as shown in Figs. 9 and 10. It is thus necessary to conclude that, if only small volumes of water are injected during the course of the test, r_i changes only slightly and, therefore, as r_i is considerably greater than r_w, the logarithm of r_i/r_w is practically constant.

If, however, larger volumes were injected during the course of the test, $\log_e r_i/r_w$ would no longer be constant and, therefore, the localized injectivity index dQ/dp_w would no longer be constant. If large enough volumes are injected, so that equilibrium conditions are attained, the corresponding pattern formula is applicable. In the case of the five-spot, conductivity (change in intake rate for change in pressure) would be:

$$\frac{dQ}{dp_w} = \frac{\pi k h}{\log_e D/r_w - 0.619} \qquad (11)$$

As D/r_w is constant, the conductivity is always constant (Fig 10, curve B).

Fig. 11 shows pressure-input tests made on the same well whose pressure-falloff curves were shown in Fig. 5 at two different dates. The localized injectivity index on June 28 was exactly the same as on December 30. The reservoir had filled considerably during this period, and the transient back pressure was greater at the start of the second test than at the start of the first. As a result the x intercept of the curve, when no water enters the well, is higher in the second curve; and, for any given pressure, less water was injected.

It should be noted here that the transient back pressure affect the determination of productivity index as well, and they should be given consideration by those concerned

"Best Bet Yet"

These oil-proof, wear-resistant, plastic tubing protectors are an integral part of the tubing collar. Made in all sizes, they prevent the metal-to-metal contact that has caused many expensive "wet" jobs in pumping wells in the past.

PATTERSON-BALLAGH
TUBING PROTECTORS
LOS ANGELES 1 • HOUSTON 10 • NEW YORK 6

mainly with primary production. A special case of this, which is of interest to those engaged in water flooding, concerns the comparison of flowing and pumping water-flood oil production. If a producing well which has previously been allowed to flow its production is put to pumping, it takes a long period of time for the pressure gradient to readjust itself to the lower sand-face pressure, during which time the rate of production continually decreases. When a well has been pumping, and is put to flowing, it will take a long time for the pressure about the well to build up, during which time the production will continually increase. Many comparisons between flowing and pumping production rates may have been misleading because of this effect.

When it is desired to compare injectivity indices of two different wells, it is convenient to divide the injectivity index by the sand thickness. This is then called the specific injectivity index. In the illustrations herein, I.I. signifies injectivity index, and S.I.I. specific injectivity index.

5. Plugging of Input Wells

a. General. — The detrimental effect of accidental plugging of the pores of the sand in input wells always presents a serious problem. In general, three types of materials present in the injected water are apt to cause plugging: (1) Suspended solids; (2) dissolved solids; and (3) organic growths. Discussion of the treatment of water to prevent plugging is outside the scope of this paper; therefore, the usual causes will only be mentioned here.

Suspended solids include foreign matter and dirt of all kinds. Most common and difficult to remove are iron oxide and hydroxide. Most underground waters contain iron as soluble salts in the ferrous form. On exposure to air they change to the ferric state and, due to hydrolysis, form a fine reddish-brown precipitate of hydrated ferric oxide. This precipitate may be removed by coagulation, settling, and filtration. However, the treater water containing dissolved oxygen is apt to attack the iron pipes and pick up additional amounts of iron oxide on the way to the well. The water may be made inactive by deaeration or treated by other means so as to prevent it from attacking iron.

Other important plugging materials are substances like clay, silt, and other earthy substances that can easily be removed from the water by filtration. The plugging of the sand face by drilling mud and cuttings when cleaning out a well may be important, but there seems to be no way at present of determining the damaging effect of such materials. Thorough swabbing of the well before introducing the water seems a wise precaution.

Dissolved solids include soluble carbonates and other salts which may precipitate on the sand face or in the pores of the sand about the well. When fresh water is used, especially if treated with lime or soda ash, the soluble bicarbonates usually present may be precipitated in the pipe or in the sand as insoluble calcium or magnesium carbonates. When natural brines from a source other than the oil sand are used, reactions are liable to occur between the injected brine and the interstitial water in the sand which may result in the formation of insoluble compounds. Insufficient study has been given to this matter. The presence of barium in one water and sulfate in another, for example, results in the precipitation of barium sulfate. At least one known treating plant has to remove barium from flood water during the treating process.

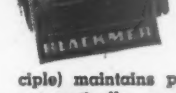
Certain low forms of plant and animal life, notably bacteria and algae, flourish in tanks and collecting ponds used in water-injection systems. These forms are often fibrous or gelatinous, so that they are particularly effective as plugging agents.

HELMERICH
AND
PAYNE, Inc.

PHILTOWER
TULSA, OKLAHOMA

BLACKMER
PUMPS
The Key to

• LOWER PUMPING COSTS
• SUSTAINED PUMPING CAPACITY
• PUMP DEPENDABILITY



Write for Bulletin 102 PUMPS FOR THE PETROLEUM INDUSTRY which explains why the "Bucket Design" (swinging vane principle) maintains pumping capacity by automatically compensating for wear and how the buckets, when finally worn out, are easily replaced and the pump restored to its normal capacity.

BLACKMER PUMP COMPANY
1940 Century Ave., Grand Rapids 9, Mich.

SERVING THE PETROLEUM INDUSTRY FOR OVER 40 YEARS
REFINERY PUMPS | BULK STATION PUMPS | HAND PUMPS

In general, it has been found that materials fine enough to enter the pores are the most effective plugging agents. Larger materials simply accumulate and pile up on the sand face, and have a minor, although still important, plugging effect.

Using the empirical relationship:

$$r = (8.85)\ (10^{-5})\ \sqrt{k/f} \qquad (12)$$

where:

r = calculated radius of the average capillary, centimeters.

The average statistical capillary sizes for certain cores of Bradford sands have been calculated.[8] The calculations indicate that the pore spaces have extremely small diameters, as the following examples show:

Core No.	PK-5	H-4
Permeability (millidarcys)	128	2,550
Porosity (per cent)	22.65	10.1
Calculated average pore diameter (centimeters)	0.0042	0.028
Calculated average pore diameter (inches)	1/600	1/90

Studies of thin sections of Bradford sands and other evidence indicate that many pores are much larger than indicated by these calculations, and that only the larger pores transmit the oil. Many others, of course, are much smaller than the average, but the values cited give some indication of the minuteness of particles which enter the pores and cause plugging action. Plugging tests were made using the finest particles obtained by elutriating a commercial brand of portland cement. The elutriated particles had an average diameter of 0.004 cm. or 1/640 in.; and it was found that they would enter and plug the pores of core H-4, but not those of core PK-5. Likewise, a 2½ per cent suspension of ultrafine aquagel in a 1 per cent sodium-hydroxide solution would enter and plug the pores of a 24.1-md. Bradford sand, but not one whose permeability was 12.7 md.

These experiments indicate that foreign particles in input water normally would have to be smaller than those of ordinary portland cement to cause effective plugging of the pores of average sands. They show also that the coarser the sand, the more it is apt to be plugged by moderately sized particles.[9]

It should be emphasized that no well penetrates a single layer of sand whose permeability is equivalent to the average permeability of the sand body. Any normal sand consists of a series of more or less disconnected layers having different porosities, permeabilities, and liquid saturations. There will be a different pressure gradient in each layer, and each layer, therefore, will have a different transient back pressure. On closing the well in, it is to be expected that beds with low transient back pressure will continue to take water for some time. At the surface only the summation of the various back pressures will be noticeable. It is possible that a relatively permeable layer containing no oil, such as a bed originally containing only gas, may show a low transient back pressure even after large quantities of water have been injected. In such cases, which are believed to exist in the Clintonville field, and many others, the wells may show a steep pressure-falloff curve even though the oil pay is being pressured properly. When this occurs, the producing wells have a high water-oil ratio, because of water bypassing through the permeable or water-saturated layers of the sand.

The fact that different layers of sand have different transient back pressures has been employed in the deliberate selective plugging of the more permeable beds. The back flow from the tighter beds should prevent the plugging material from entering. whereas the flow into the more open ones should plug them effectively.

Muskat[10] has discussed the theoretical effect of a small zone of material around the well bore, which has a different permeability from the rest of the sand. He shows

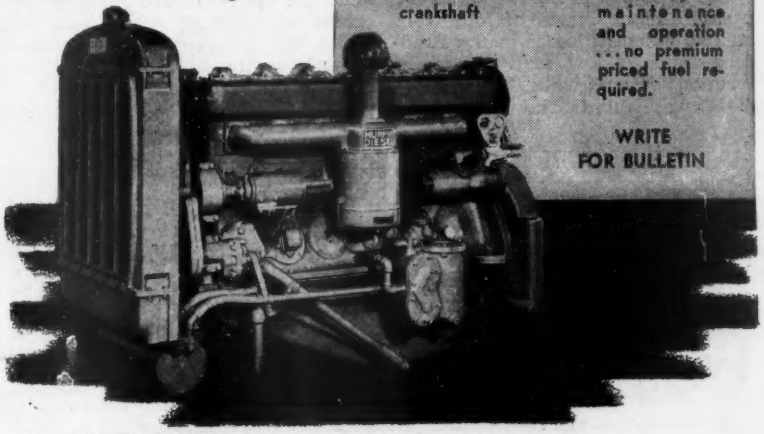
MURPHY DIESEL ENGINEERED FEATURES THAT MEAN...
More Power, More Profit!

To make every power-job a profit-job, specify MURPHY DIESELS in new heavy-duty equipment . . and when overhauling present equipment re-power with Murphy Diesels for better performance and economy. Sound engineering and rugged construction, relatively light weight and compactness, with heavy-duty ability and long trouble-free service life, have won Murphy Diesels their reputation for dependability. Consider these outstanding features:

MURPHY DIESEL
Outstanding Features:

1—MURPHY UNIT INJECTOR
2—24-volt electric starting
3—Ample filters for lubricating and fuel oils
4—Plain open combustion chamber
5—Copper-lead-alloy, steel-backed precision bearing shells
6—Through steel tie-bolts
7—Tocco hardened crankshaft
8—Hydraulic Servo-type governor
9—Safety control
10—Oil cooler
11—Oil cooled pistons
12—Four valves per cylinder
13—Compact, relatively light in weight
14—Heavy-duty, rugged construction, for economy in maintenance and operation . . . no premium priced fuel required.

WRITE FOR BULLETIN



Murphy Diesel Model ME-6, 135 H. P. continuous, 24-hour duty, full Diesel engine.

☆ Buy Victory Bonds

MURPHY DIESEL COMPANY
5305 W. Burnham St., Milwaukee 14, Wis.
TULSA BRANCH: 416 S. Detroit Ave., Tulsa 3, Okla.

More Power
MURPHY DIESEL
Reg. U.S. Pat. Off.
More Profit

Engines: FROM 80 to 210 HP
Generators: FROM 60 to 165 KW

"FIELD-PROVEN Power"

109A

that, if the permeability of the sand in the immediate neighborhood of the well is appreciably lower than that of the sand body in general, there will be a marked decrease in the production (or injection) capacity of the well. He reports that: "These large effects, caused by small zones about the well bore, are evidently due to the highly localized character of the pressure drop in a radial-flow system about the well center."

b. Examples of declining water-intake rates.—It has been shown that the intake rate of a normal well declines during its life, at least until a constant steady-state pressure distribution is established in the part of the reservoir affected by the well. In addition, gradual plugging of the sand face by suspended solids generally takes place. By means of pressure-input curves established at intervals of a few months, it is possible to distinguish between the decrease in intake rate due to plugging from that due to fillup of the reservoir. The former shows as a flattening of the slope of the pressure-input curve (decreasing injectivity index), whereas a decrease in water-intake rate due to fillup shifts the whole curve downward.

Pressure-input curves are also helpful in indicating the value of the critical or "breakthrough" pressure, at which rupture of the formation occurs. This phenomenon will be discussed in Section 7 herein.

Fig. 12 compares input-decline and pressure-input curves of four wells on two adjacent leases in the Bradford field. A key map shows the location of the wells tested. Well B-44 was cored, and showed 52 ft. of sand of average permeability of 6.3 md. Of this, 33 ft. were over 1 md., and this section had an average permeability of 9.5 md. It will be noted that this permeability is approximately one-fifteenth of that of well 054 in the Clintonville field. The specific injectivity index at Clintonville averages 0.02 bbl. per day per psi., whereas in the case of this Bradford well it is 0.0033, or about one-sixth of that at Clintonville. On this basis the Clintonville wells should take 2½ times as much water as they do. The discrepancy might be explained by the fact that the Clintonville sand is softer, and thus probably shatters less during the shot—with a resultant smaller effective well radius.

Lease "B" has had filtered and treated water injected from the start, whereas lease "A" had unfiltered and corrosive water, which has seriously damaged the inside of the water lines. Large quantities of insoluble ferric hydroxide have been forced into the wells, and carbonates have been deposited in the tubing and liner and on the sand face. The intake rates of wells 38 and 44 on lease "B" in 1943 were 50 to 70 bbl. per day, respectively; whereas those of the offsetting wells on lease "A" were above 20 bbl. per day. Part of the difference in rate is caused by a difference in pressure. However, the pressure-input curves on the right side of Fig. 12 show that the injectivity indices of the "B" wells are approximately twice those of the "A" wells. This means that the "B" wells are twice as efficient in injecting water into the sand. The difference can be ascribed mainly to the unsatisfactory water used on lease "A."

Individual well gages are not available for either lease; therefore, the effect of the low intake rates on oil production cannot be determined. On lease "B" the pressure was increased from 1,000 to 1,200 psi. in March 1942, which increased oil production about 25 per cent. The effect of injecting water slowly is to lengthen the time it takes to recover the oil, and the slow rate may well cause a loss of physically recoverable oil.

The use of poor water also affects the cost of production in causing corrosion of surface lines and tubing in the wells. A total of 56 out of 97 intake wells on the "A" lease have had holes develop in the tubing. Not a single string of tubing has had to be repaired on the "B" lease.

6. Controlled Plugging

a. Producing wells. — For many years controlled plugging has been applied to oil-producing wells, in order to prevent the entrance of undesirable quantities of gas or water into the well from certain parts of the sand body. The most commonly used method of controlled plugging is known as "squeeze cementing." This measure is a process whereby cement slurry is forced under pressure into the interval of sand from which unwanted water or gas enters the well.

Chemicals have been introduced into the water-bearing sands to form voluminous precipitates on contact with the water and to shut off the entrance of the water into the wells. Such chemicals are antimony trichloride, silicon tetrachloride, ethyl silicate, and others. Another group of chemicals used to selectively plug oil wells reacts with certain ions present in the formation water, forming precipitates which plug the pores of the sand and prevent water from entering the well bore. A third group of chemical plugging agents is a mixture of chemicals in aqueous solution which, after a predetermined time, precipitates and firmly plug the sand. In order to direct the flow of this mixture of chemicals into the desired sand layer, mechanical devices like packers are used.[11] It is not known that wholly satisfactory results have ever been obtained with such chemicals.

Plugging with organic plastics that are introduced into the sand as liquid, and that polymerize into solids under the effect of the formation temperature, has recently been successful.[12]

b. Injection wells. — In recent years much thought has been given to the possibility of selectively plugging specific sand layers penetrated by injection wells in areas where secondary recovery is practiced. Controlled plugging of injection wells should seal off undesirable

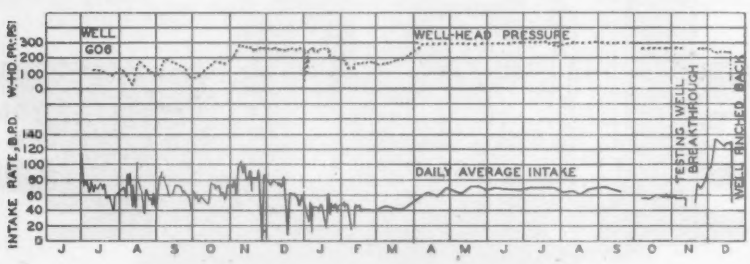


Fig. 21—Input and pressure history of Well G06

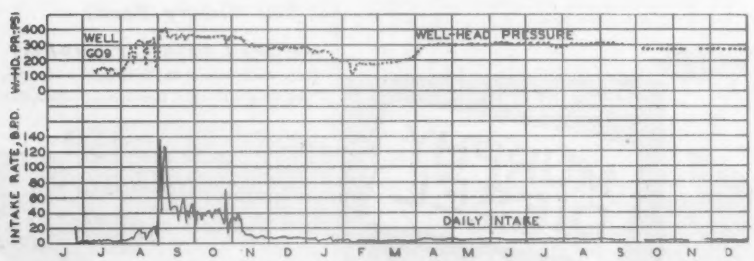


Fig. 22—Input and pressure history of Well G09

No More Fighting!

In Germany or Japan—The War is Over.

No More Fishing!

In the Oilfields . . . For Operators Who Use

BUTLER Automatic CASING SPIDERS and ELEVATORS

The Butler Casing Spider "speaks for itself" when it performs for you. You can't afford to be without one.

Butler Equipment has been proven to be safe with any load that a derrick can be made to stand up under.

REGARDING BUTLER CASING ELEVATORS:

Butler Slip Ring Casing Elevators are made with adjustable brackets which adapt them more specifically to cementing and washing down purposes, eliminating necessity for stripping elevator or plug container to make connection. Adjustable Jaws of Bracket hook on to top of Casing Coupling leaving threads of the Coupling open to receive Cementing Plug Container, or any other type cementing connection may be screwed in Coupling while Casing is suspended on the Elevator. Discontinuance of yokes adapts Butler Elevator for B-J Hook, and without affecting use of slips.

Butler Products Sold Only Through Supply Store

The NEW DEAL SPECIALTY CO.

—INC.—

OKMULGEE, OKLA., U.S.A.

NEW DEAL PIPE CLEANING MACHINES • PIPE STRAIGHTENING MACHINES • OIL FIELD SPECIALTIES

sand strata, regardless of the irregularity of the well walls. After the oil-production rate in a regular flood pattern has passed its peak, subsequent production is at a relatively low rate—which can be maintained only by maintaining full pressure at the water-intake wells. As a result of the high water-intake pressures, the produced water-oil ratio increases because larger and larger quantities of water pass through highly permeable sand strata which already have been watered out. Finally, the ratio of water to oil produced becomes so large that continued operation often is uneconomical. Consequently, plugging of watered-out strata improves the economy of operation by reducing the quantity of water injected into the intake wells and that pumped with oil from the producing wells and, therefore, lessens the power consumption for pumping, as well as wear on mechanical equipment. Selective plugging also allows increased pressures in the latter life of a flood in order to recover all possible oil from the sands of lower permeability. Increasing the pressure late in the life of a flood is ordinarily not feasible, unless bypassing of water through watered-out sands can be minimized.

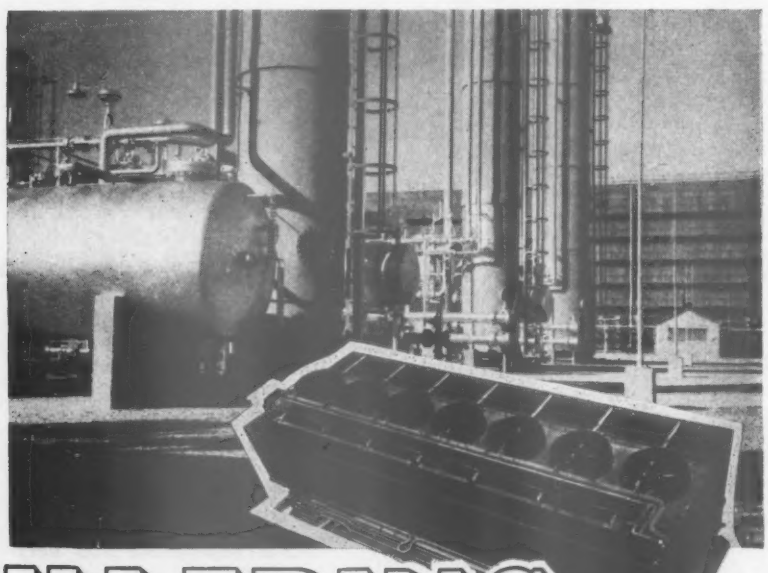
The major difficulty in effectively plugging selected sand sections of water-intake wells is that the wells, as a rule, have been shot and have been in operation for some time. As a consequence, the diameter of the well bore varies and vertical-shot cracks exist between the tight strata and the looser watered-out sands. It is thus difficult, and often impossible, to use packers or the like to direct a plugging medium into a specific sand. In the Bradford field, intake wells are generally completed with 1½ or 2-in. tubing, with packers set and cemented at the top of the sand, to withstand the operating pressure. Also, it frequently is very difficult to determine exactly into which part of the sand body the water enters because only a small fraction of the wells is cored and, therefore, only a few permeability profiles are available. Even when permeability profiles are at hand, the dry permeability profile does not necessarily depict the actual injection profile or give a true picture of the possible variation of intake rates with depth.

Consequently, the "spotting" of the plugging agent is difficult and often impossible, and recourse must be had to a method which uses the variations in flow velocities to carry the plugging medium to the desired section of the wells. Without adequate control, however, "flow-velocity plugging" may cause more harm than good by plugging all parts of the sand and causing a decrease not only in the rate of water intake, but in the oil-production rate as well.

The obvious indication of the success of a controlled plugging operation in watered-out sand strata is the production rates of the oil wells. If the plugging has been truly selective, the oil-production rate will remain constant, or increase; but the water throughput and, consequently, the water-oil ratio will decrease appreciably.

The effectiveness of plugging can be determined also by noting the change in the localized injectivity index, which is directly proportional to the effective permeability and thickness of the sand. If the plugging agent decreases the effective permeability or effective thickness of the sand, or both, the localized injectivity index will be reduced. Thus, a decrease in the injectivity index indicates the extent of plugging, but does not necessarily indicate which strata have been plugged off. This is illustrated in Fig. 13, which shows the effect on the localized injectivity index of three successive treatments of a well with wax emulsion.

It is suggested that pressure-fall-off curves, which show the summation of transient back pressures


Marley Cooling Tower

HAERING GLUCOSATES

FOR CORROSION, SCALE & ALGAE CONTROL in the PETROLEUM INDUSTRY

Write on your letterhead for "ECONOMICS OF WATER CONDITIONING"

WE READ WATER

D. W. HAERING & CO., Inc.
GENERAL OFFICES:
205 West Wacker Drive, Chicago 6, Ill.

with time, might show the selectivity of a plugging operation. The decline of back pressure when the well is shut in will be rapid in open sands, and slower in tight ones; and the back pressure recorded at the well head is the resultant of all back pressures of the various individual strata comprising the sand body. When an input well is shut in, the transient back pressure in bypassing strata will decline quickly. The tighter strata will continue to back flow, and flow currents will be set up from the tight into the bypassing strata. If the plugging process was truly selective, and if only the looser sands have been plugged, the general decline in transient back pressure as measured at the well head will be reduced. This is illustrated in Fig. 14, which shows pressure-falloff curves on a well in the Bradford pool. The well penetrates a sand 44 ft. thick having an average permeability, as estimated from a core from a nearby well, of 15 md. There is a highly permeable sand having a permeability of 70 md. in the central part of the sand body. It will be noted that curve "A" and curve "B" are virtually parallel. Curve "B" was taken after an apparently unsuccessful attempt had been made to selectively plug the high-permeability sand with wax distillate.

The operating line pressure after plugging with wax distillate was higher than the original pressure, so that the transient back pressures also are higher. However, the rate of change (as indicated by the slope of the curve) did not change. Later, an experimental plugging with chemicals was performed, which apparently was successful, as the decline in the transient back pressure of curve "C" was at a much slower rate than the decline of curves "A" and "B".

c. Plugging materials.—A patent was issued to Ryder and Bailey as early as 1927 (U. S. Patent No. 1,661,270) covering the preferential plugging of loose sands by injecting a wax-distillate fraction. The solid wax is carried by an oil fraction against the sand into which most of the injected water escapes. The authors are familiar with several tests that were made in accordance with the patent specifications, but none showed truly selective results.

A patent (U. S. Patent No. 2,264,037) issued to Haskell in 1941 covers the plugging of sands by finely divided solid particles suspended in a carrier medium. The most frequently used suspension of this type is cement or clay in water, although any other kind of suspension or emulsion in any carrier medium could be used. The use of suspension in a carrier medium for selectively plugging water-injection wells has to be controlled carefully, or the result will be harmful and undesirable, as the tight sands as well as loose ones may be plugged.

The means to force the suspended particles into loose sands, and not into tight ones, finds its origin in the difference in transient back pressure between loose and tight sands. The suspension is forced at full line pressure into the input tubing. When the suspension is opposite the sand, the pressure at the well head is greatly reduced—causing the transient back pressures in the more permeable sands to dissipate rapidly while those in the less permeable sand strata decline slowly. Thus, the back flow from the tight sand, as well as the water pressure from the surface, forces the solids into the most permeable sands.

As previously described, particles of materials approximating the size of the sand pores are the most effective plugging agents. Although certain portland cements and clays contain a large percentage of particles of the proper order of magnitude, most field applications using cement or clay for plugging sands have been failures for the following apparent reasons: The size distribution of the solid particles was too wide; there was too great a differ-

ARE YOU LOOKING for a rod packing that will really stand up in hot oil service?

Try J-M No. 270 Interlocked—the rod and plunger packing that can't unravel or come apart because it has no jackets to wear through, no plaits to become loose. The asbestos yarns used in its construction are actually *interlocked* to form a solid, integral structure!

And another feature that means better performance—it is braided square to provide a tight seal with minimum gland pressure.

J-M No. 270 Interlocked is only one of the many Johns-Manville Packings that are designed especially for oil industry service.

* * *

At your Supply House—or write Johns-Manville, 22 East 40th Street, New York 16, New York, for catalog and details.

Johns-Manville PACKINGS & GASKETS

ence in the density of the solids and the water; and, possibly, the rigidity of the solid particles caused them to deposit at the entrance of the capillaries without being forced into them. A solid which appears to have more desirable properties than cement or clay for controlled plugging of intake wells, and which can be distributed more evenly and stably in water, is wax. Based upon studies made at Pennsylvania State College, oil producers in the Bradford field, in collaboration with Pennsylvania Grade Crude Oil Association, are performing field experiments at the present time using wax emulsions for selectively plugging water-intake wells.

Some operators have used aquagel as a plugging agent. The suspension is forced under pressure into the sand, and that deposited against the tight sands is removed by allowing the well to back flow. Complete information as to the effectiveness of an aquagel suspension is not available, but it is reported to have done some benefit in certain wells. Inasmuch as a thick suspension of aquagel in water will not penetrate ordinary consolidated sands, it appears likely that it will be successful mainly in those wells that have been ruptured by excessive pressure.

Numerous other plugging agents have been suggested and tried in either laboratory or field experiments. Yuster and Calhoun[25] have reviewed, in a recent article, methods of selective plugging with special emphasis on secondary recovery.

7. Formation Ruptures or "Breakthroughs"

a. General observations. — When the pressure at the bottom of an input well is raised above a certain critical value, the well takes much more water than it normally should. In other words, the injectivity index increases suddenly when a certain sand-face pressure is exceeded.

Sometimes the increase in intake rate is manifold when the critical pressure is exceeded. Some wells 2,075 ft. deep in the Kanesholm (Pennsylvania) pool would take 15 to 17 bbl. of water per day under 1,600 psi. well-head pressure, and 92 to 110 bbl. a day when the pressure was at 1,750 psi. Another well subsequently described in more detail took 4 bbl. of water per day when the pressure was 120 psi., and 130 bbl. a day when the pressure increased to 400 psi. Large increases in water-intake rates usually are accompanied by prompt and spectacular increases in the rate of water production of nearby oil-producing wells. Often several wells surrounding the water-intake well are affected; sometimes the water-production rate in one well only is increased; and, in one instance, none of the surrounding wells showed an increase in the water-production rate.

On some properties, the increase in injectivity index is small at pressures exceeding the breakthrough pressure, and can be detected only by making a "pressure vs. water input" test on the well. Inasmuch as only a very large increase in water production usually can be detected in an oil-producing well, moderate increases in injectivity indices probably are common and unnoticed, and give rise to serious but unsuspected inefficiencies in many operations. Numerous examples of large and small breakthroughs are given in the following paragraphs, and the critical pressure for a number of wells is given in Table 1.

The following observations have been made in connection with the phenomenon of "breakthrough."

1. The critical pressure at the sand face ranges between 1.0 and 1.7 psi. per foot of depth in the northwestern Pennsylvania and eastern Illinois fields. Values for other fields also fall within this range, although there is insufficient information definitely to establish the range for each of them.

CUT DOWN COSTLY DELAYS . . . with PENN SAFETY CONTROLS

• Minor troubles in engine lubricating and cooling systems are bound to occur . . . but there is no excuse for allowing them *to grow into major breakdowns.* Let a PENN Safety Control guard against such engine damage and serious operation delay. Then, if oil pressure fails or jacket water temperature rises too high, the PENN Control goes into action . . . sounding an alarm, flashing a warning light or shutting down engine operation. Precious time and money are saved!

Easily installed on any internal combustion engine—old as well as new—PENN Safety Controls are built in three basic models: oil pressure only, water temperature only, and a combination of the two.

Learn more about this low-cost protection now, write *Penn Electric Switch Co., Goshen, Ind.* Export Division: 13 E. 40th St., New York, 16, U.S.A. In Canada: Powerlite Devices, Ltd., Toronto, Ontario.

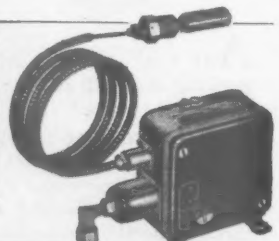
TYPICAL FUNCTIONS OF PENN SAFETY CONTROLS

Diesel Applications. Sounds an alarm only . . . closes maggetic fuel valve and sounds alarm . . . closes magnetic fuel valve only . . . closes magnetic fuel valve and opens pilot relay.

Battery Ignition Applications. Opens battery circuit and sounds an alarm . . . sounds an alarm only . . . opens battery circuit only.

Magneto Ignition Applications. Sounds an alarm only . . . grounds dual magneto . . . grounds magneto only . . . grounds magneto and sounds an alarm or lights a signal light.

Dual Ignition Applications. Opens battery circuit and grounds magneto.



Penn Combination Pressure and Temperature Control

PENN AUTOMATIC CONTROLS

FOR HEATING, REFRIGERATION, AIR CONDITIONING, ENGINES, PUMPS AND AIR COMPRESSORS

Be SAFE with

X-L QUALITY
OIL WELL TUBING
COUPLINGS

Plain or External Upset for standard tubing, made from steel. Tested by Comparator to assure strict adherence to A.P.I. standards. Available in all sizes. When ordering, please use our catalog description; it will save time and error.

WHEELING MACHINE PRODUCTS COMPANY
WHEELING, WEST VIRGINIA

ACCURATE PROMPT...

Analyses of Oils
And Gases
including
Low Temperature Distillation
Of Gases
Crude Oil Evaluations
Wax Determinations

OIL AND GAS DIVISION
of the

SHILSTONE
TESTING LABORATORY

HOUSTON
301 M & M Bldg. Fairfax 4139
2817 W. Dallas Hadley 7726
NEW ORLEANS
510 Gravier St. Raymond 2040
CORPUS CHRISTI
615 Old Robstown Rd. Phone 9907

BROKEN OVERHEAD GASOLINE LINE FIRE KNOCKED OUT IN SIXTY-FIVE SECONDS

NEW DUAL-STREAM NOZZLE
Further increases fire-fighting effectiveness of

DUGAS EXTINGUISHERS

Pictured above is a rigorous test conducted at the DUGAS Division Test Grounds, under observation of Underwriters' Laboratories and Factory Mutual Laboratories. Burning gasoline escaped at the rate of 10 gallons per minute under 50-lb. pressure through three hacksaw cuts in a pipe 13 feet above ground.

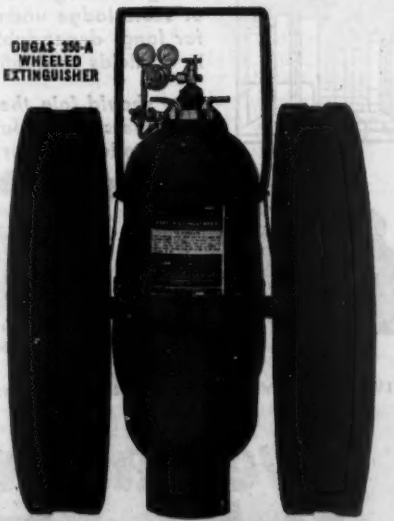
Inset shows how quickly the fire was knocked out by DUGAS Dry Chemical after it had been allowed to burn for one full minute. Using the straight stream from the new dual-stream nozzle on a No. 350-A DUGAS Wheeled Extinguisher, the overhead gasoline fire, including blaze on ground, was extinguished in exactly 65 seconds.

NEW DUAL-STREAM NOZZLE...

deals effectively with spill fires and fires difficult to reach because of height or obstructions. Designed for use with DUGAS Wheeled Extinguishers, the new dual-stream nozzle greatly increases fire-fighting range and effectiveness. A turn of the handle gives a straight stream with a range of 45 feet—or a fan stream with a range of 15 feet.

Quick Facts About DUGAS Dry Chemical
1—For extra-hazardous fires involving flammable gases, liquids, greases or electrical equipment.
2—Not an electrical conductor.
3—Non-toxic, non-corrosive, non-abrasive.
4—Not affected by extreme cold or heat.

DUGAS 350-A WHEELED EXTINGUISHER



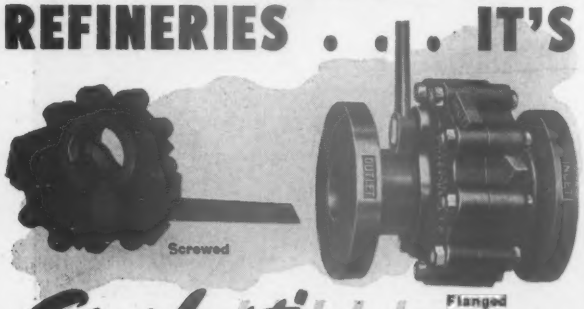
Write today for complete information regarding DUGAS Wheeled Extinguishers with the New Dual-Stream Nozzle... and DUGAS Hand Extinguishers.

AN ANSUL PRODUCT
DuGas
THE MASTER OF FLAME

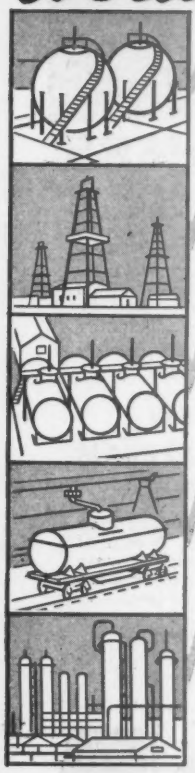
Approved by Underwriters' Laboratories, and Factory Mutual Laboratories.

ANSUL CHEMICAL COMPANY, MARINETTE, WISCONSIN
DUGAS DIVISION

FOR OIL FIELDS AND REFINERIES . . . IT'S



Everlasting VALVES



In oil fields and refineries, Everlasting Valves are serving on: drilling boilers; blow-off lines; emergency throttle service on drilling engines; gasoline and oil loading racks; storage and measuring tanks; spray lines; . . . everywhere that *quick action*, full opening and drop-tight closing are vital.

Trouble-free — no sticking, no binding, no wedging or clogging — their operation is SURE and SAFE. WHY? . . . because their unique design eliminates the causes of usual valve failures.

For instance... the Everlasting Valve disc rotates parallel to — and constantly on — the seat, regrinds itself with each turn, keeps the seal EVERLASTING-ly tight. Each sealing part is free — self-compensating to expansion and contraction. The disc cannot work loose and choke the straight-through flow. Nor can dirt or scale lodge under the disc. Built for long, dependable, *hard service* in oil fields and refineries.

You should join the ranks of satisfied users of Everlasting Valves — write today for our Bulletin!

Blow-off valve for 350 lb. Oil Field Boilers.

EVERLASTING VALVE CO., 49 Fisk Street, Jersey City 5, N. J.

Everlasting Valves FOR EVERLASTING PROTECTION

FROM MULES TO MODERN POWER

Beginning at Petrolia back in 1908 with only a span of mules, our operations during the past thirty-seven years have extended into California, Colorado, Oklahoma, Arkansas, Mississippi, Louisiana, and all of Texas. From Electra, Smackover, Mexia and Burkburnett to the present, our records show more than 2,000 oil and gas wells drilled under every condition. We have helped push derricks higher — and pipe lower, past 12,000-foot levels in the search for crude. We have used everything from the makeshift equipment of other days to our present modern rigs with gasoline, heavy steam, electric and diesel power. The experience we have gained is invaluable and the 250 men in our organization have a knowledge of drilling second to none in the business. We have come a long way in these thirty-six years and we're proud of our part in helping develop the industry. We look forward to new development with the same anticipation that we had in 1908.

HEAVY STEAM—DIESEL GASOLINE AND ELECTRIC

Al Buchanan

DRILLING CONTRACTOR

SAN ANTONIO, TEXAS

XUM

TABLE 1—BREAKTHROUGH PRESSURES OF INDIVIDUAL WELLS

1	2	3	4	5	6	7	8	9	10
						Critical pressure			
Line No.	State	Field	Well	Lease	Depth (ft.)	Well head (psi.)	Bottom hole (psi.)	Bottom-hole pressure ÷ depth	Approximate critical pressure minus overburden pressure (psi.)
1	New York	Wellsville	.....	Marsh	760	825	1,155	1.5	395
2	New York	Bolivar	.....	Norton-Whitehill	1,800	1,500	2,270	1.26	470
3	New York	Ceres	Various	Eleven-Mile	1,270	1,650	2,200	1.73	380
4	Pennsylvania	Bradford	Name withheld	.....	1,320	750	1,320	1.0	0
5	Pennsylvania	Bradford	Name withheld	.....	1,387	1,250	1,850	1.33	460
6	Pennsylvania	Bradford	165	Columbia Hill	1,700	850	1,585	0.93	—285
7	Pennsylvania	Bradford	Various	Various	Various	700-900	Various	1.0-1.2	
8	Pennsylvania	Bradford	Name withheld	.....	1,335	1,400	1,980	1.48	345
9	Pennsylvania	Bradford	Name withheld	.....	1,340	1,600	2,180	1.63	840
10	Pennsylvania	Kanesholm	2SS23	Coontown	2,075	1,900	2,725	1.3	650
11	Pennsylvania	Clintonville	023F2	Cross	950	850	1,220	1.3	270
12	Pennsylvania	Clintonville	028F3	Marshall	1,140	1,150	1,645	1.4	505
13	Illinois	Siggins	GO7F2	Chrysler	261	250	363	1.39	100
14	Illinois	Siggins	GO6F2	Chrysler	294	375	502	1.70	205
15	Illinois	Parker	KO11	Linn	268	175	291	1.09	25
16	Illinois	Parker	JO13	Terrell	279	260	392	1.40	113
17	Illinois	Parker	MO13	Linn	317	200	337	1.06	20
18	Kansas	Garnett	.....	Bowman	660	425	710	1.07	50

Comments

1 Narrow valley between two hills. Later applied 1,300 psi. without break.
3 Wells LL-26, NN-25, MM-25, and 8. 1,600 psi. could be carried safely, but at 1,650 psi. water came through to oil wells in 16 hours.
4 This well is an anomalous area where many wells have shown peculiarly low breakthrough pressures.
5 This well was accustomed to break periodically, and within a few hours large amounts of water appeared in a neighboring producing well.
7 From "Selective Shutoff of Watered-out Sands," by John C. Calhoun, Jr., Pennsylvania State College sixth annual technical meeting, Progress Report No. 72, Bradford District Producers Association, p. 37, November 1941.
13 At start of flood. Adjacent wells showed break at 375 psi. later in life of flood.
14 Adjacent wells broke at 250 psi. at start of flood, and at 375 psi. later in life of flood.
18 Later applied 750 psi., a factor of 1.6

The range of critical pressures cited applies to depths between 260 and 2,075 ft. (see Table 1).

2. Critical pressures vary from well to well, and in one area (east of Rixford) in the Bradford field the critical pressures appear to be abnormally low, and of the order of 0.9 psi. per foot of depth or less. Apparently the critical pressure is lower in the early life of a well than it is after a considerable volume of water has been injected into the surrounding sand.

3. If, after a breakthrough has occurred, the pressure is reduced below the critical value, sometimes the well resumes its normal water-intake rate; but, if the critical pressure has been exceeded for several days or weeks, the wells usually do not resume their previous water-intake rates, but continue to take water at a high rate, which fluctuates in an irregular manner.

4. Breakthroughs are almost always followed by the appearance of water in one or more neighboring oil-producing wells within a few days, and the water passes quickly from one well to another.

5. Breakthroughs are characterized by definite increases in injectivity indices. The increase in the value of the index is never gradual, and the graphs of the pressure-input points are straight lines with sharp discontinuities.

b. Mechanism of rupture. — The observations cited indicate without much question that the breakthroughs are a result of a rupture of the formations. From the behavior of injectivity indices, it appears that cracks must be formed in or at the top of sand bodies, which extend rapidly through the rock and, in some cases, at least extend to or close to nearby wells. In mild ruptures it is possible that the cracks extend only a short distance away from the intake well and have principally the effect of increasing the surface (effective radius) of the well. In severe ruptures the cracks probably extend to offsetting producing wells. Cases have been reported when turbid water, or even cement slurry from wells in which the critical pressure was exceeded, appeared in adjoining wells.

Muskat[14] has investigated mathematically the effect of fractures on the productive (or injective) capacity of a well. His discussion deals mainly with fractures in limestones, but it is equally applicable to sandstones. He states:

"A fracture of even a small width may have an effective permeability hundreds of times as great as that of the limestone proper. For a real fracture of width w may evidently be considered as equivalent to an open linear channel of equal width. Now for viscous flow conditions the carrying capacity of such a linear channel for unit pressure gradient may be shown by classical hydrodynamics to be given by:

$$Q = \frac{w^2}{12\mu} \qquad (13)$$

where μ is the viscosity of the liquid. The equivalent permeability of the channel is, therefore:

$$k = \frac{w^2}{12} = \frac{10^8\, w^2}{12} \text{ darcys} \qquad (14)$$

if w is expressed in centimeters. Hence a fracture of only 0.1 mm. width will have a permeability of 833 darcys (833,000 md.), whereas the permeability of the limestone proper will usually be on the order of 0.01 darcy (10 md.). In fact, the total fluid-carrying capacity of a radial system of radius 45 ft. consisting of a limestone of permeability 0.01 darcy can be carried by a single linear fracture 45 ft. long, of depth equal to that of the radial system, and of width 0.126 mm."

The critical pressure varies with depth and is, therefore, some function of the pressure of the overburden. Assuming the specific gravity of water-soaked sedimentary rocks to be about 2.2, the pressure of the overburden would be approximately 1.0 psi. per foot of depth. The breaks occur from 0 to 850 psi. in excess of the pressure exerted by the overburden. In Pennsylvania the average is around 300 psi.; and in Illinois, where the formations are less consolidated, it is about 75.

It has generally been assumed that the phenomenon of formation rupture is explained by a simple lifting of the overburden along a bedding plane. Direct evidence that such horizontal parting does occur was obtained by Paul D. Torrey.[15] He states that in a deep well in Cameron Parish, Louisiana, 7-in. casing was run to a depth of a little over 10,000 ft. A series of horizons believed to be possibly producing were successively gun-perforat-

Fedelco

•Six years of development and practical application have proved Fedelco Liquid Plastic Coating a remarkably effective new protection against corrosion.

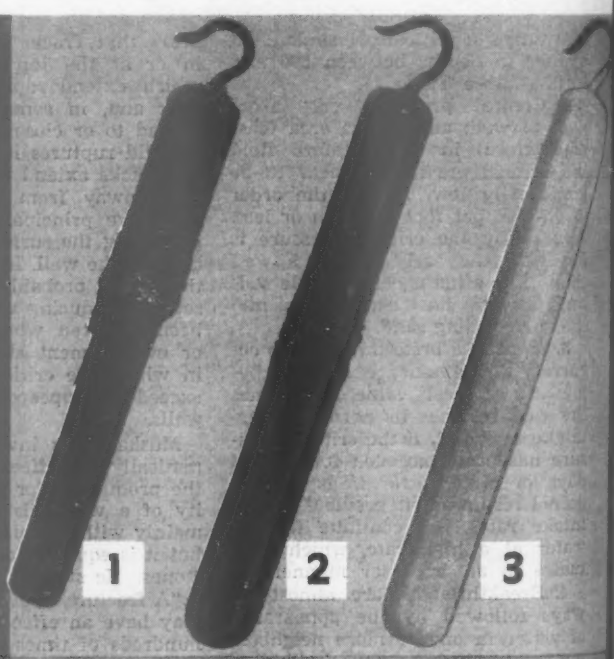
Properly applied, it protects wood, metals, and concrete for long periods against mineral acids, alkalis, and their salts, against moisture, and electrolysis.

Fedelco Liquid Plastic Coating comprises most inert plastic resins. When the coating is applied by dipping, spraying, or brushing, the solvent evaporates, leaving a sheet of actual plastic.

This plastic coating is tough, tenacious, and highly flexible, so that it does not crack under bending or expansion or contraction of the material to which it is applied.

Fedelco is remarkably resistant to abrasion; does not chip; has high dielectric strength; will not ignite once it has thoroughly dried; withstands severe shock from temperature changes, and while the coating is not resistant to high temperatures, it will withstand up to 200 degrees Fahrenheit.

FEDELCO HAS THESE UNUSUAL PROPERTIES AND CHARACTERISTICS



These three steel torpedoes have been kept in a 45% solution of ferric chloride for 2054 hours (nearly 3 months). Torpedo no. 1 had no protective film of any kind; nos. 2 and 3 were coated with Fedelco Liquid Plastic Coating FE-70. As the photos show, no. 1 is nearly half eaten away; no. 2 shows deposits of corroded metal from no. 1, and ferric chloride salt at the water line, over the FE-70; no. 3 has been washed with clear water. The FE-70 coating on both nos. 2 and 3 is still fully intact, still giving 100% protection to the steel.

FEDERAL ELECTRIC

225 North Michigan Ave.

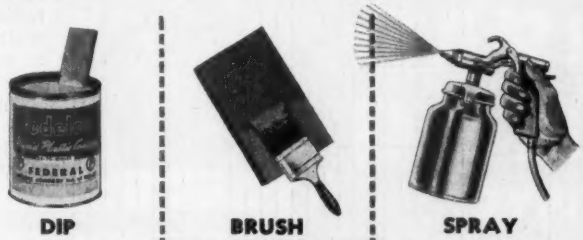
Liquid Plastic Coating

NOW AVAILABLE

Fedelco Liquid Plastic Coating FE-70 is now available for immediate delivery. This product is not a cure-all. It will not withstand aromatic or chlorinated hydrocarbons, ketones, some ethers and esters, or certain concentrated or strong oxidizing acids. But its protection is so broad, so long-lasting, that it is worth investigating.

DIP, BRUSH or SPRAY

Fedelco Liquid Plastic Coating may be applied in either of these three ways. When dipped or sprayed, it should be thinned with FE-70 thinner only.



For general maintenance work, not less than three coats should be applied, and five to seven coats for processing equipment. The degree of protection is directly proportionate to the amount of Fedelco applied to the surface.

What Users Say

"On two metal tanks, the coating answered our purpose perfectly. The job of applying it was really very simple, and we had no trouble."

★

"Extensive research to determine its resistance to corrosion in salt water showed absolutely no signs of corrosion in a period of over five months of 24-hour service, and 100% protection from any possible solution of copper and brass."

★

"We have found it to withstand the action of our muriatic acid and hypochlorite satisfactorily. We applied six coats."

★

"Numerous tests for over five months indicate excellent qualities as a protective coating for industrial equipment."

★

"We have conducted extensive tests on many different kinds . . . Of all the products tested so far, none has stood up as well as your product."

★

"As an insulating material and protective coating in our anodizing process with 10% chromic acid solutions at 95° F., it has performed satisfactorily over a period of 8 months."

★

What Tests Show

Extensive tests have been conducted in our own and in users' laboratories, and in practical, day after day service. The results of some of these tests are given below, to indicate what may be expected of Fedelco Liquid Plastic Coating.

The coating was in excellent condition after it had been used with the following products for the time indicated:

Kerosene, 4 years; lubricating oil, 4 years; Foamite, 1 year; salt water, 4 years; sulfuric acid, 10%, 14 months; sewage treatment, 4 years; atmosphere, 4 years.

The coating was in *good* condition after these tests; 80 octane gasoline, 1 year; fuel oil, 2 years; ethyl alcohol, 18 months; sulfuric acid, 25%, 14 months; and after 18 month tests on each of the following gases: chlorine, sulfur dioxide, hydrogen sulfide, flue gas, carbon dioxide.

The coating was in *poor* condition after 3 months in 100 octane aviation gasoline; 3 months in full strength carbon tetrachloride; 2 months in concentrated sulfuric acid.

For any specific use, consult Fedelco engineers, who can advise you on the probable results and best application.

Packed for Easy Handling

Fedelco Liquid Plastic Coating is packed in convenient 1-gallon and 5-gallon containers for easy on-the-job handling. Coverage varies but can be estimated at 200 square feet per gallon on average surfaces.

WRITE FOR BULLETIN

A technical data bulletin describes properties, characteristics, and other tests. Write for Bulletin FE-70.

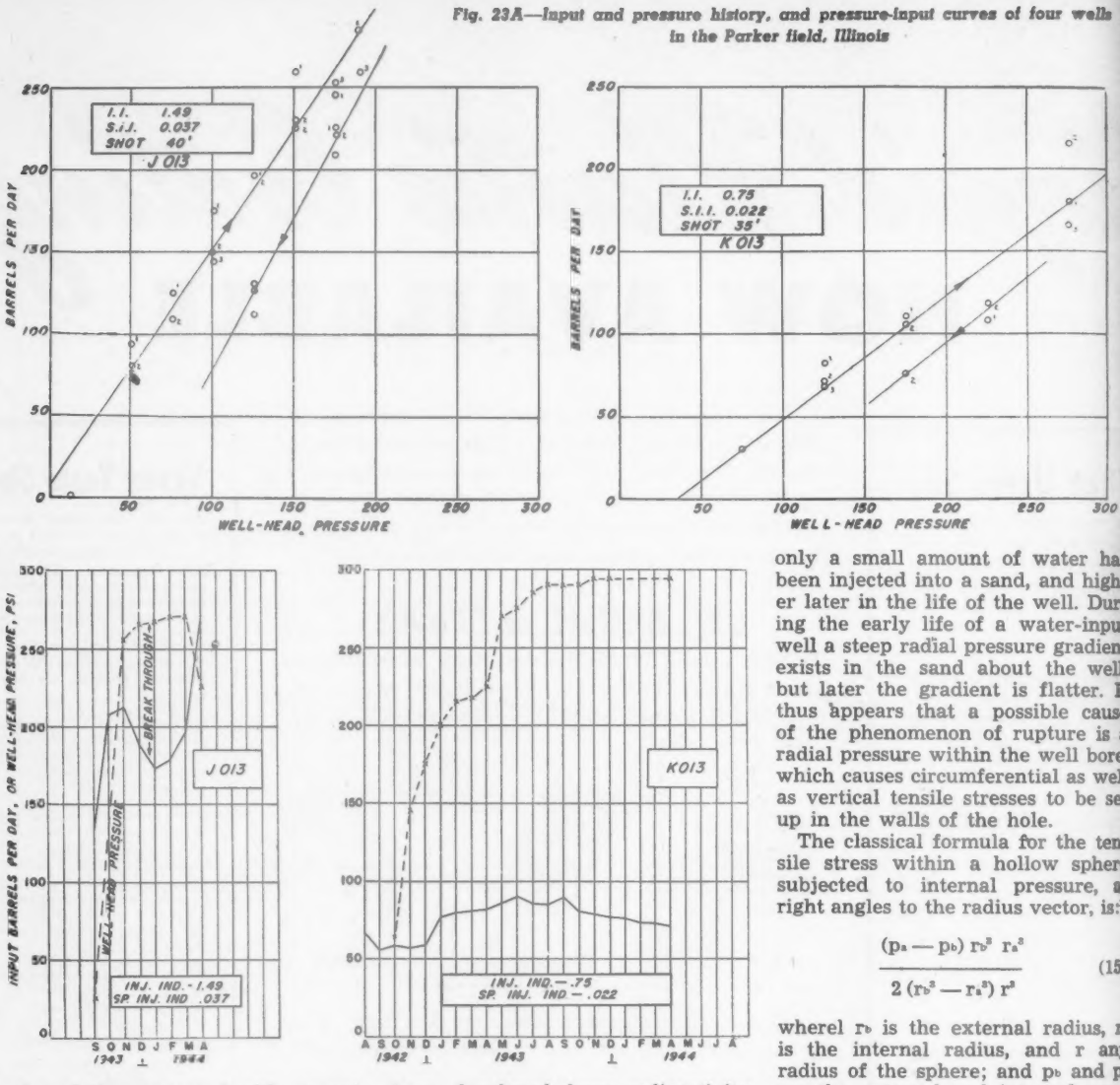
Fedralite Shot Hole Casing . . . Fedelco Plastic Pipe . . . Fedelco Liquid Plastic Coating . . . . . Fedelco Tank Cleaning Service . . . Electrical Advertising Signs . . . .

COMPANY, Inc., of TEXAS

Illinois

XUM

Fig. 23A—Input and pressure history, and pressure-input curves of four wells in the Parker field, Illinois



ed, and then squeezed with cement. The casing collapsed at about 7,000 ft. while being perforated to make a production test. A promising show of oil had been encountered at 9,000 ft. during the previous tests. Rather than drill an entirely new hole, it was decided to mill through the casing above the point of collapse, set a whipstock, and sidetrack the well. The sidetracked hole penetrated several water-bearing horizons which had previously been tested and squeezed with cement, and one of these horizons was cored. The core showed that thin layers of cement had penetrated the soft sand, and the core recovered consisted of alternating layers of sand and firmly set cement in beds from ½ to 6 in. thick. A verticality survey of the sidetracked hole was made; and it was found that, at the point where the core was taken, the cement had pushed its way back 15 ft. away from the original hole. Torrey also reports that similar information has been developed from radioactivity surveys of successive squeeze jobs where carnotite, a radioactive mineral, was added to the cement slurry.

However, several of the features noted in connection with breakthroughs in water-injection wells are apparently not entirely explained by the simple lifting of the overburden. If the beds parted, and if overlying formations were lifted, it would be expected that, once the overburden pressure had been exceeded, any additional water injected would simply lift them further. In that case, the injectivity index after the break would be virtually infinite, and almost any quantity of water could be injected at a pressure only slightly exceeding that necessary to lift the overlying formation. If that were true, the pressure-input curve, instead of breaking into a new straight line, would curve upward and become vertical.

There is some evidence that the critical pressure is a minimum when only a small amount of water has been injected into a sand, and higher later in the life of the well. During the early life of a water-input well a steep radial pressure gradient exists in the sand about the well, but later the gradient is flatter. It thus appears that a possible cause of the phenomenon of rupture is a radial pressure within the well bore, which causes circumferential as well as vertical tensile stresses to be set up in the walls of the hole.

The classical formula for the tensile stress within a hollow sphere subjected to internal pressure, at right angles to the radius vector, is:[39]

$$\frac{(p_a - p_b)\, r_b^3\, r_a^3}{2\,(r_b^3 - r_a^3)\, r^3} \qquad (15)$$

wherel r_b is the external radius, r_a is the internal radius, and r any radius of the sphere; and p_b and p_a are the external and internal pressures, respectively.

If r_b is much greater than r_a, then:

$$\frac{r_b^3\, r_a^3}{(r_b^3 - r_a^3)\, r_a^3}$$

is nearly unity, so the formula reduces to:

$$\tfrac{1}{2}\,(p_a - p_b)$$

for the circumferential tensile stress at the inner wall. The corresponding formula for a cylinder with no stress applied to the walls axially is:

$$p_a - p_b$$

It is well known that the maximum stress inside a thick-walled cylinder or sphere under internal pressure is at the inner wall, and past a certain limit little strength is gained by increasing the wall thickness. Thus, a pressure exceeding the tensile strength of the rock about a well, plus the confining

UNIFORM DESIGN AND PERFORMANCE

GARDNER DENVER

TYPE "FX" POWER PUMPS

- Uniform design of all sizes throughout the entire line—*a Gardner-Denver exclusive.*
- Large Bearing areas on eccentrics reduce wear to a minimum—*resulting in long, trouble-free operation*
- Divided fluid end construction—*cast of Gar-Durloy Alloy mixture developed especially for mud pump fluid cylinders.*

THE CONTINENTAL SUPPLY COMPANY
General Offices: DALLAS, TEXAS
EXPORT DIVISION
30 Rockefeller Plaza New York City, N. Y.
Representatives
MEXICO - ARGENTINA - ENGLAND - TRINIDAD
BRAZIL - VENEZUELA - COLOMBIA - CHILE

CONTINENTAL

SERVING THE OIL AND GAS INDUSTRIES

Columbus had a hard job, but he whipped it.

Building up today's oil reserves is no easier. Oil is where you find it...often in places as remote and inaccessible—even as dangerous—as those encountered by Columbus.

GSI is ideally suited to tackle tough exploration problems. We have the experience, the personnel, and the equipment ready to make seismic surveys anywhere in the world. Call in GSI.

The Gulf of Mexico is the locale for this open water operation by a GSI Crew.

GSI

GEOPHYSICAL SERVICE INC.

DALLAS, TEXAS

force, would inevitably start a fracture.

The confining force in the case of a well is the overburden pressure in a vertical direction. However, even in well consolidated formations at shallow depths, where plastic flow does not occur, at least some of the overburden pressure will act as a horizontal confining pressure as well. For when a cube of unit dimensions is subjected to a compressive stress (s) in the direction of any axis, it is shortened s/E in the direction of the pressure and elongated σ s/E along each of the two axes at right angles to the direction of the pressure: where σ is Poisson's ratio and E is the modulus of elasticity. When a well is drilled into a consolidated rock possessing elastic properties, the walls of the hole will move inward a small amount because of the horizontal elongation of the rock resulting from the vertical pressure. Pressure inside the well will counteract this horizontal confining pressure, and just balance it when the well pressure is equal to the pressure exerted by the overburden.

The water-input wells studied by the authors were all drilled into consolidated sandstones and shot with nitroglycerin. Studies of the effect of a shot by the authors and others indicate that the most notable result is the creation of a system of cracks in vertical planes radial to the axis of the hole. The horizontal confining pressure of the overburden forces the wall of the cracks together tightly. When the pressure inside the well exceeds the confining pressure, the walls will move outward, for the rock will be shortened horizontally and expanded vertically. As the cracks widen, a stress concentration will be set up at the distal ends, tending to extend the cracks.

It has been suggested by D. P. Krynine[17] that the rupture may consist of a shearing fracture in a conical plane or planes, concentric with the well, and extending obliquely upward. There are two forces near the well: the horizontal force created by the water pressure, and the vertical force created by the weight of the overburden. The resultant of these forces before rupture must be balanced by a reaction perpendicular to a conical surface concentric with the well. When the horizontal pressure exceeds a critical value, rupture will take place by shear in the plane of the cone. There may be irregular and multiple surfaces of rupture. The cracks would rarely come to the surface, but usually intersect one or more neighboring wells. In the unusual case where a break occurred without any increase in water production of the surrounding wells, it is possible that the break reached a near-surface bed.

On the basis of tensile strength of the rocks alone, it would be expected that the cracks would probably be horizontal, parallel to the bedding. However, pending a more thorough stress analysis, it appears possible that vertical or inclined cracks may also be formed.

c. Examples of breakthroughs.—An example of a slight breakthrough is shown in Fig. 15, which depicts a pressure-input test of well 023F2 in the Clintonville field. This well penetrated sand from a depth of 948 to 959 ft., which had an average permeability estimated from nearby cores of 80 md. Water had been turned into the well November 30, and the well had taken a total of 730 bbl. on December 2, when the first test was run. Pressure was increased by 50-psi. increments, and a slight increase in the localized injectivity index took place when the pressure reached 825 psi. The well was shut in for 12 hours, and the test repeated. The well then took slightly more water at the same pressures, because the transient back pressure had diminished during the shut-in period. However, the localized injectivity index remained essentially unchanged, and the same slight break

On the job at Wilshire Oil Company, Inc., Norwalk, Calif.—an Elliott Turbine-Blower unit.

THE success of the fluid "cat" cracking process is contingent upon continuous operation. Thus, the blower which furnishes the air for circulation and regenerating the catalyst has often been called the "heart" of the plant. Elliott centrifugal blowers are measuring up to the demand for smooth, non-stop performance in many of the catalytic cracking plants supplying our nation's requirements for high octane gasoline.

The turbine or motor is linked with the blower in a complete Elliott-built unit, with the advantage of placing performance responsibility on a single manufacturer.

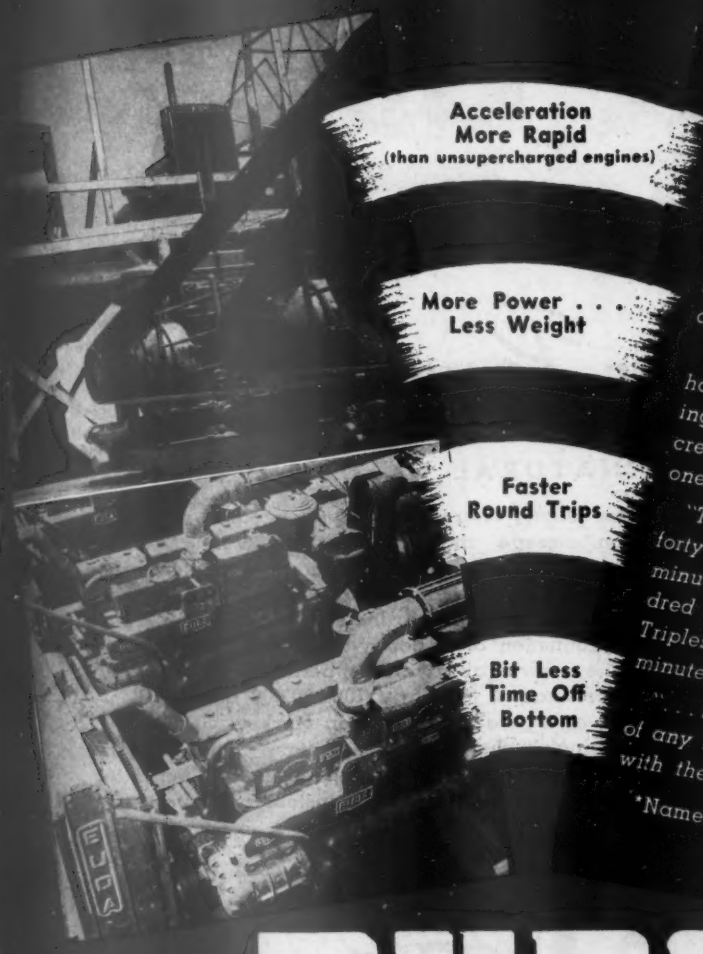
Full details on these units upon request. Consult our nearest district office.

P-1071A

ELLIOTT COMPANY
Centrifugal Blower Dept., JEANNETTE, PA.
Plants at: JEANNETTE, PA. • RIDGWAY, PA.
SPRINGFIELD, OHIO • NEWARK, N. J.
DISTRICT OFFICES IN PRINCIPAL CITIES

BUDA 6-DC5-1879
SUPERCHARGED
DIESEL
military
secret now!
ARMY
E
NAVY

oilfield SUPERCHARGED POWER



Acceleration More Rapid (than unsupercharged engines)

More Power . . . Less Weight

Faster Round Trips

Bit Less Time Off Bottom

Read what these *owners of BUDA 1879 Supercharged Drilling Engines have to say:

"This pair of engines is the most powerful and fastest pair of drilling engines I have ever handled in my fifteen years of drilling experience."

"The engines have had 900 hours service on this well, it being drilled to 6,635 feet . . . the crew pulled the 6,636 ft. of pipe in one hour and fifteen minutes . . ."

"This pair of engines pulled forty-two Triples in forty-seven minutes . . . also sixty-four hundred feet of 4½" drill pipe in Triples in an hour and forty minutes."

". . . there's not another engine of any make or size to compare with them."

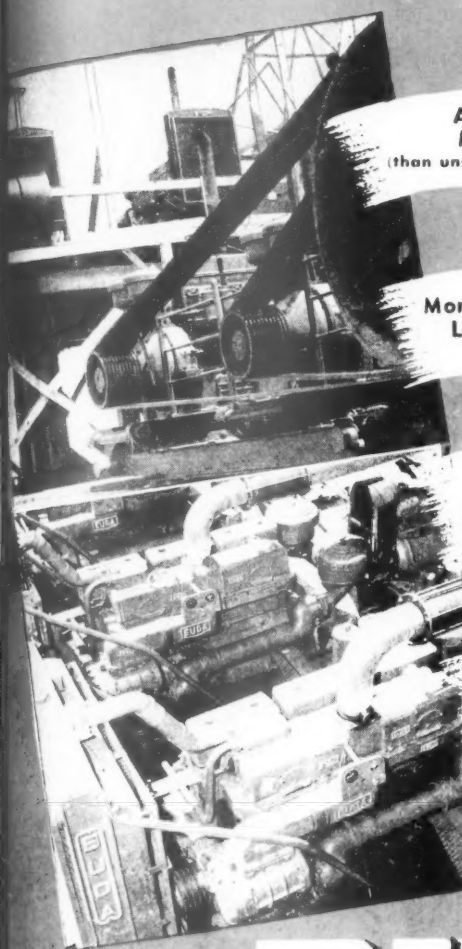
*Names furnished on request.

BUDA

NOW it can be announced publicly: Here's the engine that did such a standout job, exclusively for the Army in Europe during the war—the BUDA 1879 Supercharged Diesel Drilling Engine. Now after a year of testing by drilling contractors in this country—after a year's service without any breakdowns or repairs—this superpower is available to *you!* The BUDA 1879 Supercharged Diesel* is the most up-to-the-minute drilling engine available today. Write or wire for full details.

*BUDA Supercharged Butane and Natural Gas Engines will be available soon.

SUPERCHARGED *oilfield* POWER



Acceleration More Rapid (than unsupercharged engines)

More Power . . . Less Weight

Faster Round Trips

Bit Less Time Off Bottom

Read what these *owners of BUDA 1879 Supercharged Drilling Engines have to say:

"This pair of engines is the most powerful and fastest pair of drilling engines I have ever handled in my fifteen years of drilling experience."

"The engines have had 900 hours service on this well, it being drilled to 6,635 feet . . . the crew pulled the 6,636 ft. of pipe in one hour and fifteen minutes . . ."

"This pair of engines pulled forty-two Triples in forty-seven minutes . . . also sixty-four hundred feet of 4½" drill pipe in Triples in an hour and forty minutes."

". . . there's not another engine of any make or size to compare with them."

*Names furnished on request.

BUDA

15434 Commercial Ave.
HARVEY (Chicago Suburb) **ILLINOIS**

BUDA Nozzle Testers

BUDA Oil Field Jacks

BUDA ENGINE & EQUIPMENT CO.
Houston, Texas—1810 Texas Ave. Wichita Falls, Texas—1024 Indiana Ave. Dallas, Texas—904 South Ervay St. Odessa, Texas—1300 North Grant St. Kilgore, Texas—216 Knowles St. Corpus Christi, Texas—3900 Westland Drive.

W. L. SOMNER CO.
Shreveport, La.—419 Lake St. Tinsley, Miss. Heidelberg, Miss.

BUDA ENGINE SALES & SERVICE
Tulsa, Okla.—521 W. Archer St.
Oklahoma City, Okla.—834 S. E. 29th St.
Seminole, Okla.—322 E. Broadway
Salem, Ill.—211 E. Schwartz
Great Bend, Kan.—2016 Broadway
Casper, Wyo.—132 North Wolcott

PRODUCTION EQUIPMENT CO.
Los Angeles 1, Calif.—851 Gage Avenue
Long Beach 7, Calif.—3271 Cherry Avenue
MIDWAY TOOL CO.—Mt. Pleasant, Mich.
McEWEN BROS., INC.—Wellsville, N. Y.
INDUSTRIAL MACHINE SUPPLY & MOTOR WORKS—Artesia, New Mexico

EXPORT OIL FIELD DIVISION
BUDA ENGINE & EQUIPMENT CO.
New York 23, N. Y.—253 West 64th Street

Chemical Grade
HYDROCARBONS
Iso-Pentane
Normal Butane
Iso-Butane
Propane

MORE *Power* TO YOU

WITH WARREN'S STABILIZED NATURAL GASOLINE

Nearly a quarter-century of growth in experience and research — in production, storage and transportation facilities — has made Warren one of the largest manufacturers, marketers and exporters of Natural Gasoline and Liquefied Petroleum Gases. Supplementing plants previously owned and operated by the company, the production of a dozen modern, new gasoline plants during the prewar and wartime period will bring our total capacity (production) to nearly 100,000,000 gls. in 1945. In addition to its own production, Warren markets 400,000,000 gls. annually, bringing the total sales volume to more than 500,000,000 gls. a year. Thus Warren has been privileged to serve the armed forces and our regular customers in wartime.

WARREN

WARREN PETROLEUM CORPORATION

Manufacturers, Exporters and Marketers of Natural Gasoline and Liquefied Petroleum Gas

Tulsa, Oklahoma

Export Terminals: Corpus Christi, Port Arthur and Norsworthy, Houston, Texas, Lake Charles, La., and Marcus Hook, Pa.

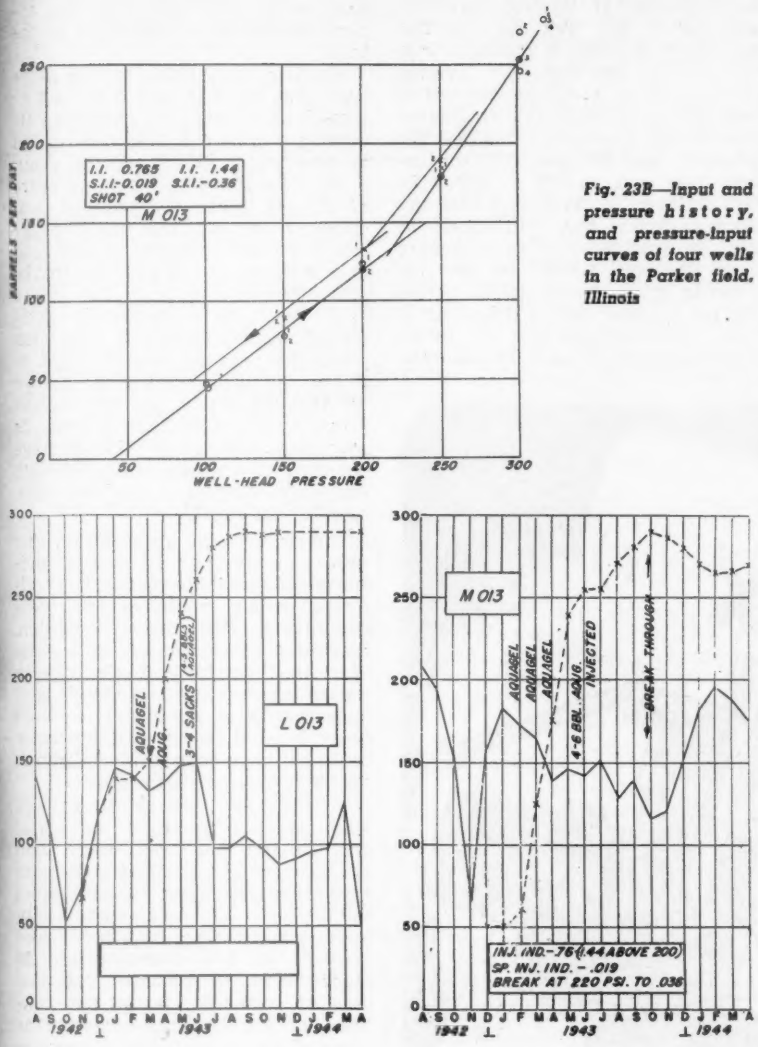


Fig. 23B—Input and pressure history, and pressure-input curves of four wells in the Parker field, Illinois

in the curve occurred when the pressure reached 825 psi. On the basis of this test, the well pressure in the field was subsequently set at 750 psi. which was believed to be a safe intensity, not likely to cause breaking through.

A similar curve is shown in Fig. 16 for well D-2, in the Bradford field. In this well the top of the sand is at 1,292 ft., and there is an estimated 50 ft. of sand having an average permeability of about 20 md. The straightness of the line (consistency of localized injectivity index) past the break is notable. Fig. 17 is the pressure-input graph for another well on the same lease. This well broke slightly at a pressure of 850 psi., and severely when the pressure reached 1,100 psi.

Well E-1 (Fig. 18) is an interesting example of a well in which a severe break took place when the pressure reached 1,250 psi. Subsequently a pressure of 1,310 psi. was maintained on the well for 2 days, during which time the water-intake rate increased. Another test then was made, this time decreasing the pressure by increments. While the pressure was being decreased from 1,280 psi. to 1,025 psi., the localized injectivity index of the well was greater than normal, but less than when the pressure was raised above 1,250 psi. At a pressure of 1,025 psi. and below, the localized injectivity index was the same as the index before the break, which it had previously maintained while pressures were increasing to 1,250 psi. The top of the sand in this well was at 1,387 ft.; and, from cores from other wells on the same lease, it is estimated that the sand was about 40 ft. thick and had an average permeability of about 5 md.

An interesting example of a group of wells that broke through, but not at the same pressures, is shown in Fig. 19. These wells are in the eastern part of the Bradford field, and were drilled on a seven-spot pattern with a spacing of 240 ft. between adjacent water wells. The sand averages 40 ft. in thickness, and its top varies between 1,318 and 1,379 ft. in depth. The relative location of the wells is shown on a key map in the lower part of the illustration. The water was first turned into the wells, September 1930, but (because of proration) the pressure was maintained at a very low intensity during 1931, and never exceeded 320 psi. at the plant. Well-head pressure readings are not available.

The pressure was raised in February 1932 to 1,200 psi. and the wells took between 20 and 40 bbl. of water a day each. In October the pressure was raised to 1,450 psi. Well C-4 responded by taking water at the rate of 110 bbl. a day, and this high rate continued to increase, until it reached a rate of 140 bbl. a day in January, even though the pressure in the meantime had been lowered to 1,000 psi. Throughout the rest of the year the well was probably controlled by pinching the valve at the well head, although no actual record of this operation could be found. Wells C-1 and C-2 showed anomalous intakes of 70 bbl. of water a day in October, but resumed their normal intake rate as soon as the pressure had been lowered. The intake rate of well C-3 increased slightly with the rise in pressure, but no more than would normally be expected—and probably rupture did not take place in this well.

The water-intake pressure was raised again during 1933, and in July attained 1,400 psi. when well C-1 broke through and its water-intake rate increased to a peak of 250 bbl. a day in December, after which the valve was pinched back. In October the pressure was increased to 1,600 psi.; and wells C-2 and C-3, which previously had withstood a pressure of 1,400 psi., broke and took large quantities of water. When the pressure was lowered to 1,250 psi. in December, they resumed their normal intake rate.

Subsequently the pressure was gradually increased to 1,600 psi. in May 1934, at which pressure well C-2 broke—apparently permanently, as its water-intake capacity thereafter was high and fluctuated widely. Well C-3, however, withstood this pressure of 1,600 psi.

In summary, at a pressure of 1,450 psi. one well broke permanently, two temporarily, and the fourth not at all. A year later the second well broke permanently at a pressure of 1,400 psi. The third and fourth wells withstood a pressure of 1,400 psi.; but the third broke permanently, and the fourth, temporarily, at 1,600 psi. Six months later the third broke permanently at 1,600 psi. but the fourth withstood that pressure and did not break through.

Referring to the key map in Fig.

19, the critical pressure appears to increase in a southwesterly direction, but has no detailed relation to depth, as the shallowest well withstood the highest pressure.

An example of the permanent rupture is shown in Fig. 20, which is a pressure-input curve of well GO6 in the Siggins pool, Cumberland County, Illinois. A core of the well showed 31.2 ft. of sand, with an average permeability of 70 md. On increasing the pressure, the water-intake rate increased 0.023 bbl. per ft. a day for each 1 psi. pressure increase. At a pressure of about 380 psi. the water-intake rate started increasing at the rate of 0.082 bbl. per ft. per day per psi. The history of the well is shown in Fig. 21. During the first few months the well-head pressure fluctuated, and the water-intake rate fluctuated accordingly. During most of 1943 the pressure was 300 psi., and the intake rate was steady at about 70 bbl. per day. In November 1943 the pressure-input test illustrated in Fig. 20 was made. The following week the well started to take increasing quantities of water, reaching 130 bbl. per day on December 5. This high rate of flow of water caused a pressure drop in the well-head connections. The well was apparently irreparably damaged by the test.

Another well, GO9, in the same pool (Fig. 22) had only 2 ft. of permeable sand, with an average permeability of 30 md. The well started to take water at the rate of about 4 bbl. of water a day at a pressure of 120 psi. When the pressure was raised to 300 psi. the water-intake rate increased to 20 bbl. a day; and, at a pressure of 400 psi., the intake rate attained a peak of 130 bbl. a day. The rate subsequently fluctuated around 40 bbl. a day; and, when the pressure was reduced to below 300 psi., input rate leveled off at 6 bbl. a day, and maintained that rate for more than a year. In this case apparently the damage resulting from this breakthrough was only temporary, and the rupture healed itself.

The majority of the wells on this 40-acre tract showed similar evidence of breakthroughs. The oil-producing wells, which were equipped to flow their production, produced water and oil at a ratio of more than 20 to 1. Fluorescein tracer injected into an input well appeared in a producing well 22 hours later, showing that the water could not have been passing through the sand in a normal manner.

In order to determine through what part of the sand the water was passing, one well which had not been tubed was filled with fresh water by circulating upward from the bottom. Electrical-conductivity tests revealed that salty water was entering at two places within 20 ft. of the top of the sand. The passage of water is clearly not confined to one horizon, however, as many of the wells started to produce water from upper horizons back of the casing.

This acreage was condemned as unfloodable until the tests previously described indicated the cause of the trouble. Unfortunately the breaks appear to be permanent, and the lease will probably continue to produce at an uneconomic water-oil ratio for the rest of its life.

In the Parker pool, Clark County, Illinois, two wells viz., JO13 and MO13, broke through at pressures of 265 psi. to 285 psi., although two intervening wells operated safely at 280 to 290 psi. Pressure-input and input-decline curves of the four wells are shown in Fig. 23-A and 23-B.

Acknowledgment

This paper is the result of a pooling of the ideas, opinions, and information of several engineers in the Pennsylvania fields. Circumstances were such that the majority of the material had to be provided and prepared by the two authors.

Complete
STUFFING BOX
ASSEMBLY
all in
ONE
UNIT
PACKING GLAND
HANDLE
GLAND FOLLOWER
PACKING RINGS
SPACER
JUNK RING
BODY
This "American" pumping well Christmas tree is the only really modern stuffing box now being sold. Its installation saves from 12 to 14-inches over a regular stuffing box hookup, which is particularly advantageous in long stroke pumping units.
The entire pumping head assembly is included in this one unit . . . a stuffing box, pumping tee with bleed-er outlet, and a check valve. Sucker rods can be pulled through body, using gland as a bell nipple.
AMERICAN
IRON AND MACHINE WORKS CO.
OKLAHOMA CITY, OKLAHOMA
PRODUCTS FOR PERFECT . . . PERFORMANCE
Office & Warehouse, Houston, Texas. Export office: 420 Lexington Ave., New York City, N.Y. — California Representative: Hooper Mch. Works, Inc., Bakersfield, California.

However, active interest and assistance on the part of the men named hereinafter made the paper possible, and they should be considered as partners in the enterprise, if not co-authors. There men are: S. T. Yuster and J. C. Calhoun, Jr., of Pennsylvania State College, and Robert B. Bossler of Bundred Oil Corp.

Others who provided material assistance are: R. V. Hughes, J. K. Barton, M. Muskat, H. G. Botset, and Paul D. Torrey.

The authors are particularly grateful to H. C. Miller of the U. S. Bureau of Mines for his exceedingly helpful review of the manuscript.

They also acknowledge the technical assistance of William T. Rindlaub, Cal Bedeaux, J. Amorocho, Cora Dennis, O. C. Knott.

APPENDIX "A"

List of Mathematical Symbols

D = distance between input and producing well, centimeters.
E = modulus of elasticity.
f = fractional part of rock available for water (porosity of rock multiplied by the gas saturation).
h = sand thickness, centimeters (or feet).
k = effective permeability, darcys.
k_o = effective permeability of sand to oil, darcys.
k_w = effective permeability of sand to water, darcys.
$\log_e$ = natural logarithm, base "e."
$\log_{10}$ = common logarithm, base "10."
p_a = pressure inside a sphere or cylinder.
p_b = pressure outside a sphere or cylinder.
p_e = pressure in reservoir, atmospheres.
p_1 = transient back pressure, atmospheres.
p_w = pressure at sand face of well, atmospheres.
Δp = difference in sand-face pressure between input and producing well, atmospheres (or psi.).
Q = rate of production (or intake), milliliters per second.
r_a = internal radius of a sphere or cylinder.
r_b = external radius of a sphere or cylinder.
r_e = distance from well, where pressure is p_e, centimeters (or feet).
r_1 = distance from well, where pressure is p_1, centimeters.
r_w = effective radius of well, centimeters (or feet).
R_w = radius of encroached water, centimeters.
s = unit stress (compressive).
t = time in days.
V = cumulative water injected, milliliters.
W = distance between like wells, feet.
w = width of a vertical fracture or channel, centimeters.
μ = viscosity of liquid, centipoises.
μ_o = viscosity of oil, centipoises.
μ_w = viscosity of water, centipoises.
σ = Poisson's ratio.

References

1. M. Muskat, The Flow of Homogeneous Fluids, 153, McGraw-Hill Book Co., New York (1937).

2. M. C. Leverett and W. B. Lewis, "Steady Flow of Gas-Oil-Water Mixtures Through Unconsolidated Sands," Trans. Am. Inst. Mining Met. Engrs. 142, 112 (1941).

3. M. Muskat, op. cit., 479 and 561.

4. A. J. Saxe and S. T. Yuster, "Mathematical Analysis of Field Results," Producers M. 2 (3) 8-13 (1938).

5. This chapter is abstracted, with some modifications, from a paper by S. T. Yuster and J. C. Calhoun, Jr., entitled "Behavior of Water-Injection Wells," published in Producers M. 9 (1) 40-48 (1944).

6. "Productivity index: the number of barrels per day of gross liquid produced from a well per pound per square inch pressure differential between well and formation, referred to as a specified subsurface datum, usually the mean formation depth," A.P.I. Tentative Glossary of Terms Relating to Reservoir Behavior, Proc. A.P.I. 22 (IV) (Production Bull. No. 228) 92 (1941).

7. "Glossary Relating of Reservoir Behavior—A Report of the California District Topical Committee on Production Technology of the American Petroleum Institute," Nov. 8 (1943).

BURKE-GREIS OIL CORPORATION

Producers of Petroleum

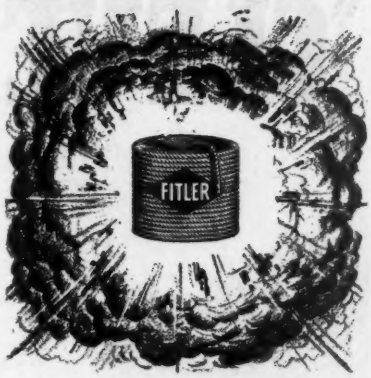
Cosden Bldg.

Tulsa - - - - Okla.

IMMEDIATE DELIVERY
6" BLACK LIGHT WT.
STEEL
PIPE

Plain end for welding and grooved for Victaulic coupling.
★ 750,000 ft. 6" I.D.—6¼" O.D.—¼" Wall
Test 900 lbs.—Pressure 650 lb.
Weight—approximately 8 lbs. per ft.
35c per ft., carload lots.
F.O.B. New Orleans, Louisiana
Dealers' Inquiries Solicited
For further information, write or call

GORDON IRON & SUPPLY CO.
Phone Wayside 2305 7152 Navigation Blvd.
HOUSTON, TEXAS



IT DOES NOT MAKE AN ATOM OF DIFFERENCE HOW YOU COMPARE ROPES — THERE IS NO SUBSTITUTE FOR QUALITY.

Backed by 141 years of manufacturing experience, FITLER ROPES are known for their strength, durability, water-repellency and flexibility.

THE EDWIN H. FITLER CO.
PHILADELPHIA, PA.
Established 1804

Bonds
Stocks
Commodities

Private Wires to All Markets

HARRIS, UPHAM & CO.

Members New York Stock Exchange and Other Principal Exchanges

107-109 Philtower Tel. 26231

Tulsa 3, Okla.

"CLEVELANDS"

EXACTLY MEET YOUR TRENCHING REQUIREMENTS

for Oil—Gas—Gasoline—Sewer and Water Lines—Drainage —Telephone and Telegraph Conduit—Building Foundations

THE CLEVELAND TRENCHER COMPANY
20100 ST. CLAIR AVE. • CLEVELAND, OHIO
CLEVELANDS Save More . . . Because They Do More

8. Penn. State Coll. Mineral Ind. Exp. Sta. Progress Rpt. 83: Project P-7-W, Mar. (1943).

9. C. F. Barb, "Oil-Field Waters of Pennsylvania," Penn. State Coll. Mineral Ind. Exp. Sta. Bull. 8, 18 (1931).

10. M. Muskat, op. cit., 403-408.

11. Paul D. Torrey, "Selective Exclusion of Fluids from Wells," Drilling and Production Practice, 205-51, Am. Petroleum Inst., New York (1939).

12. E. B. Miller, Jr., "Plug-Back Work with Plastics" (presented at A.P.I. Southwestern District meeting, Houston, June 13-14, 1944); Drilling and Production Practice, 97-103 (1944); also (prior to revision) The Oil and Gas Journal 43 (6) 92-3, 96 (1944); also (prior to revision) Oil Weekly (title: "Plug-Back Work with Plastics Shows Rapid Development") 113 (4) 65, 68, 69, 72 (1944).

13. S. T. Yuster and John Calhoun, "The Selective Plugging of Oil Sands," Producers M. 8 (7) 31-7 (1944).

14. M. Muskat, op. cit., 425.

15. Personal communication.

16. A. E. H. Love, "Elasticity," Encyclopedia Britannica, 11th edn., 9, 156.

17. D. P. Krynine, letter to authors, Feb. 17 (1945).

Bulletin Describes Method of Surveying Inundated Areas

A method of making surveys of inundated areas has recently been presented by Karl Hasselmann in a bulletin of Missouri School of Mines and Metallurgy. Hasselmann has completely described in detail a method and apparatus whereby torsion balance geophysical surveys can be made over certain flooded land areas. The techniques described, however, are not strictly limited to the use of the torsion balance but they also could be used either with the pendulum or gravimeter. As devices designed to test gravity conditions of the earth's crust require a high degree of stability to be operated satisfactorily, such surveys heretofore were not possible over water.

The method and apparatus perfected by Hasselmann makes gravitative geophysical surveys possible and as a result several previous unprospected areas have been tested in considerable detail. Therefore, the main contribution of Hasselmann's technique is that it opens water covered areas to oil exploration with gravitional geophysical instruments, and this in turn, will result in fuller, more efficient determination of possible oil pool occurrences in such regions.

Dr. A. G. Loomis, for the past 10 years in charge of production and drilling research for Shell Development Co. at Emeryville, Calif., has joined the petroleum engineering firm Keplinger & Wanenmacher, Tulsa. Before his association with Shell, Dr. Loomis conducted research for Gulf Oil Corp.

We Speak the Oilmen's Language

Since the beginning of the oil industry in Texas, we have counted thousands of oilmen among our respected friends and associates. It's easy—because we speak the oilmen's language. That's why so many oilmen, today, continue to look to the Alamo National Bank for every facility and service that a great bank affords. Come in and talk to us in *your* tongue. You'll find we understand it thoroughly.

The ALAMO NATIONAL BANK of SAN ANTONIO, TEXAS

MEMBER FEDERAL DEPOSIT INSURANCE CORP.

OWEN Type "B" TOOL CHEST--WORK BENCH

This 5 foot bench has the same construction and convenience features as the 8 foot model. It has the central drawer locking system, roller mounted drawers, large rag bin, welded and braced vise stand, skid mounting, all-steel construction, welded throughout.

The working surface is 5' by 24" with a 12" panel at the back fitted with pegs where tools can be kept within easy reach while working.

OWEN TOOL CO.

1525 WASHINGTON AVE. — CAP. 0211

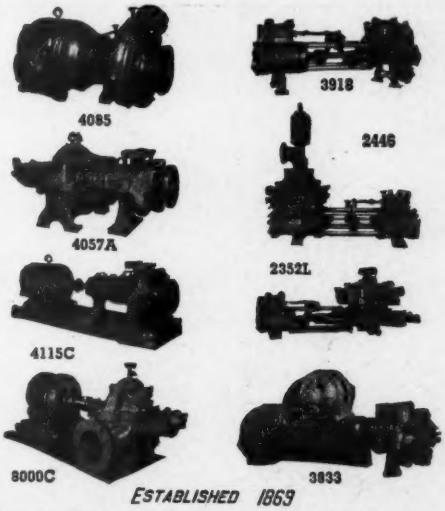
HOUSTON 10, TEXAS

DEAN BROTHERS PUMPS INC. INDIANAPOLIS IND. STEAM PUMPING MACHINERY

PUMPS

CENTRIFUGAL

RECIPROCATING



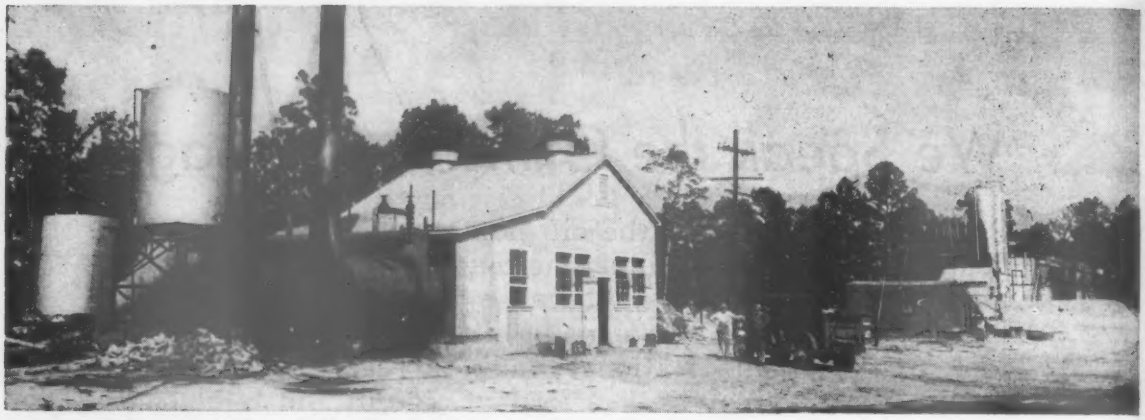
ESTABLISHED 1869

DEAN BROTHERS PUMPS INC.

INDIANAPOLIS IND.

323 W TENTH ST.

XUM



Layout of central power plant showing central treating plant and tank battery at right

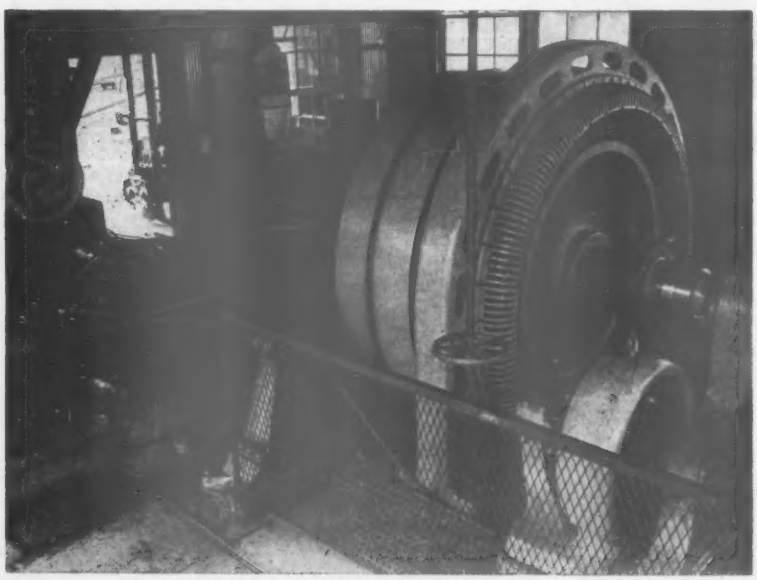
Central Electric Power Plant Solves Pumping Problem at Gilbertown

by Neil Williams

Absence of gas production in the Gilbertown field in Alabama led H. L. Hunt, the operator, to electrify the pumping of wells and operation of gathering and pipe-line stations. This article describes the central power plant and transmission system that was installed. Since the plant is operated by steam, its operation is coordinated with that of a central treating plant, where heat is required for separating the water and oil production. How this is done will be discussed in the subsequent article dealing with treating and other production practices in the field.

PRODUCTION of the Gilbertown field in Choctaw County, Alabama, consists of an undersaturated, 18° to 21° gravity, asphaltic-base type of crude oil. Individual wells produce from 30 to 100 bbl. of fluid daily. Most of them make water in amounts ranging from about 4 to as high as 65 per cent. The resulting emulsion is such that heating is needed to separate the water and handle the oil. Low pressures require artificial lifting of the oil with all wells being placed on the pump at completion.

In the absence of any gas recovery from the undersaturated oil, it became apparent early in the development of the field that some means of pumping the wells other than gas-fueled engines must be adapted. Multicylinder, internal-combustion engines using gasoline for fuel were installed initially on a number of wells. However, difficulties and costs involved in obtaining and transporting this fuel to the field made it advisable to devise some other type of power.



Interior central power plant showing 125-kw. generator driven by reciprocating steam engine

This led to a decision to electrify the field by installing a central power-generating plant supplying power not only for the individual well-pumping units but also for the gathering and pipe-line pump stations and general field use. Normally, it might have been preferred to generate this power by use of diesel engines, but since engines of this type were not readily obtainable at the time the plant was built, steam

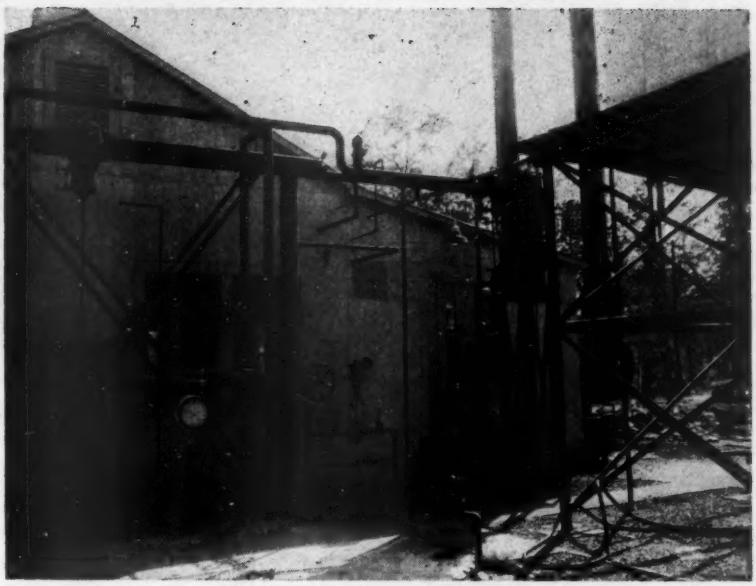
was employed instead with crude oil burned as fuel under the boilers.

The power plant has been built adjoining one of the field's two central treating stations where advantage has been taken of the availability of steam used for generating electricity to supply the heat necessary for operation of the treaters. Since engine exhaust steam is used for this purpose no additional steaming capacity is required, and substantial economies are realized by avoiding the need for operation of separate direct-fired heaters, which in this field would necessitate burning of oil for fuel. At the second treating station, located about 5 miles from the first where the steam is not available, treaters with oil-burning heaters must be used.

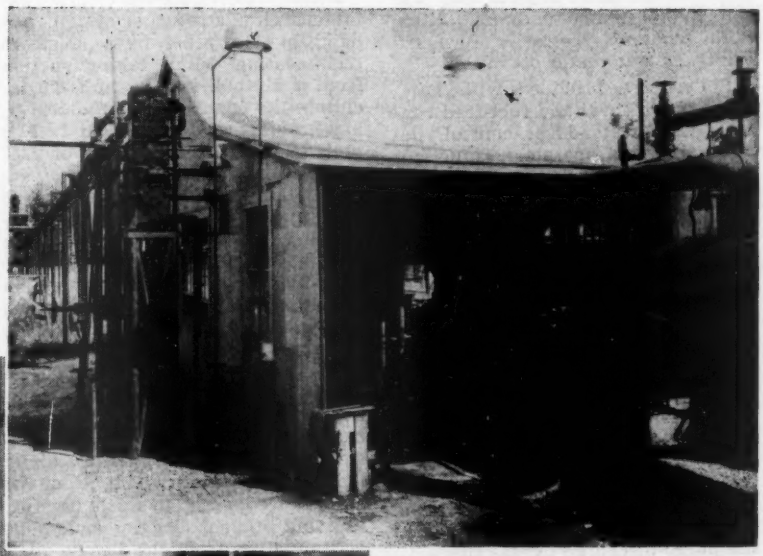
Production of the field, discovered early in 1944 by H. L. Hunt, the present operator, follows a narrow fault trend and is obtained from fractured zones in the Selma chalk at a depth of approximately 2,400 ft. and from a Eutaw sand around 3,300 ft. Both horizons, however, are not productive in the same wells. At present there are 15 wells on production, 8 of which are located in the original Gilbertown area and served by the first treating station, known as the Doggett plant, and 7 in a separate area served by the second treating station, known as the Scruggs plant.

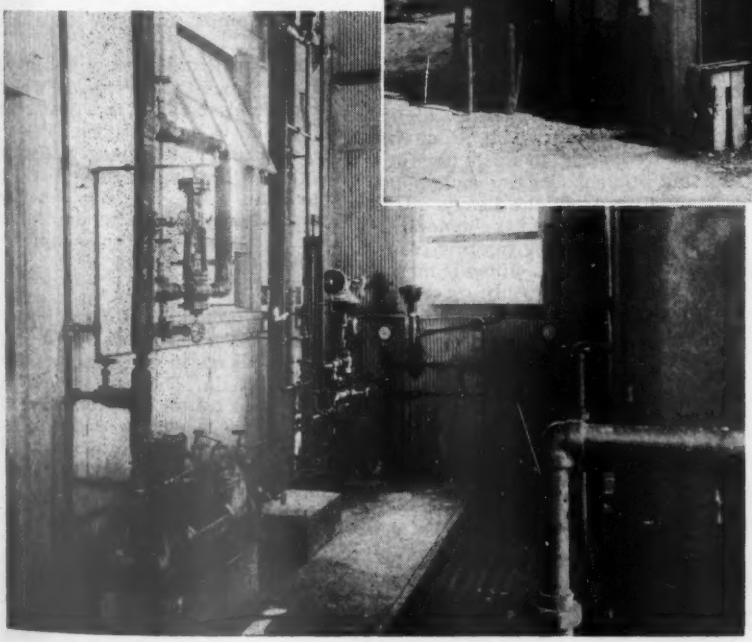
Power Plant

The power plant employs a 125-kw. generator delivering 2,400 volts at full load to the main transmission line. It is driven by a reciprocating-type steam engine, steam for which is generated by two 90-hp. boilers



Recording meter installation to measure engine exhaust steam volume to treating plant. Above is return condensate line to boiler feed-water preheater (on stand at right)





Above: Boiler installation showing feed-water preheater (on stand at left of building), and steam and return condensate lines serving treating plant. Boiler feed-water pumps are located just inside building. Barely visible on boiler is automatic water level control hookup

Left: Automatic boiler fuel feed control hookup showing feed pump (lower left), pressure-operated pump-steam regulator valve (above pump), and regulator control for fuel volume (far corner). Vertical steam-jacketed line (center left) preheats fuel

Electric-motor-powered individual pumping unit in Gilbertown field. Time clock control installation is mounted in box at right

operating at 105 psi. working pressure. Equipment had to be obtained from second-hand sources but was completely rennovated and fitted with modern accessories for efficient and automatic operation.

Boilers are provided with automatic water-level and fuel-feed controls. The water-level control, devised by the operators, functions through a float-operated check valve in the water-feed line. The feed-water-pump discharge to the boiler-water line is provided with a by-pass to the pump suction. In this there is a pop valve which opens under increased back pressure in the water line to the boiler as the float-operated valve on boiler inlet line closes with rising water level. This results in the pump discharge being recirculated to the pump suction instead of to the boilers. As the water level in the boiler tends to lower and the float-operated inlet valve opens and the back pressure in the water line drops, the pop valve in the pump-discharge bypass closes directing the pump discharge to the boiler. Pump speed to vary the water circulating rate is controlled by a boiler-pressure-operated valve in the steam line to the pump.

Feed water is preheated to a temperature of 210° F. by steam condensate returned from the treater heating coils and jackets. The condensate return line has a lead to the pump suction so that the condensate can be used as boiler-feed water if desired but at present this is not being done, as the engine exhaust steam used for heating contains a certain amount of oil which would have to be filtered. Under the circumstances it is considered more economical and convenient to use raw water for boiler feed than to filter the condensate.

Boiler burners are fed from a continuous circulating fuel system utilizing a 4½ by 2¾ by 4-in. steam reciprocating pump taking suction from a 210-bbl. supply tank. To facilitate its combustion, the heavy, low-gravity crude used as fuel is preheated to a temperature of 225° F. in circulation through steam jacketed lines. Feed to the burners is controlled by means of two regulator valves, one on the fuel line and the other on the steam line to the feed pump. These function simultaneously with any variation of boiler pressure. Burners are equipped to consume only the required amount of fuel and return all excess fuel to the system, thus minimizing coking and accumulation of carbon deposition. Automatic controls are provided with a manually operated bypass which can be opened frequently to flush the fuel line and prevent clogging by sludge accumulation from the heavy oil.

Exhaust steam from the generator engine is taken to the treating plant through a 6-in. line. Volume is measured through a pressure-recording meter on the line and a pressure of from 2 to 5 psi. is maintained on the system. This provides a means of noting quickly any faulty valves or other engine trouble that would cause steam leaks and loss of power as they would be reflected by pressure variations indicated on the recording chart.

Power-Distribution System

The main power line from the plant extends 5 miles westward to a substation in the Scruggs area, and thence 10 miles further westward to Kirby Petroleum Co.'s Langsdale field, located just across the Alabama state line in Mississippi. At the Scruggs substation, voltage of the line is stepped up from the plant load of 2,400 to 12,000 which is carried to the substation at the Langsdale terminus.

At Langsdale the system supplies the power for the main pump station of the 6⅝-in. pipe line which Placid Oil Co., a Hunt ownership, operates from that field to a tank farm and loading rack at Gilbertown, Ala., about 1½ miles east of the Gilbertown field. At that station there is a 5 by 8-in. power pump, operating at 400-psi. discharge pressure, driven by a 30-hp. electric motor. In addition there are at present five tank batteries in the field, each having a gathering pump tied into the main station and served by secondary power lines. At one of these there is a 4 by 5-in. pump driven by a 10-hp. motor, and at the others there are 2½ by 6-in. rotary pumps driven by 7½ and 5-hp. motors.

The pipe line also serves the central tank batteries in both the Scruggs and Doggett areas of the Gilbertown field. At each of these stations there is a 4½ by 6-in. power pump driven by a 15-hp. motor.

Secondary power lines lead from the power plant in the Doggett area and from the Scruggs substation to transformer settings serving the individual wells in the respective areas. At these settings the voltage is stepped down to the power requirements of the various motors. Both 200 and 440-volt motors are being used. All are 5-hp., 60-phase, 3-cycle a.c. motors but some develop their horsepower at 1,165 r.p.m. and the others at 900 r.p.m. Pumping units in each case are Emsco's DC 58-R model.

Each well installation is equipped with a time-clock control which automatically cuts off and starts up the motor at preset times. Pumping periods of the various wells are staggered throughout the field to reduce the load demands on the system at any one time, and thus diminish power-plant-capacity requirements.

Fagan Dickson, assistant attorney general of Texas, has resigned that office to engage in private law practice in Austin. Dickson served as head of the oil and gas division of the attorney general's department, and he was in that department 4 years.

W. E. Bakke has resigned as petroleum geologist, in charge of the loan department of First National Bank of St. Louis, to reenter the oil business as a geologist and producer in San Antonio.

The Present Value Of a Reserve

by ***Park J. Jones****

PART 12 OF A SERIES

The present value of a reserve depends on the rate of recovery. The two rates of recovery of particular interest to producers are uniform rates of production and rates of production proportional to reserve. The latter represents uniform rates of depletion. The present value of a producing rate at any time is equal to the rate of production and the corresponding present worth factor. Present worth factors up to 25 years hence are illustrated graphically for interest rates ranging from 2 up to 10 per cent. The present value of reserve recoverable at uniform rates of production is illustrated graphically. The present value of reserves recoverable at uniform rates of depletion is also illustrated graphically. The present value of a reserve partly recoverable at uniform rates of production and the remainder at uniform rates of depletion is illustrated by examples. The present values herein considered are before investment, taxes, royalty, and operating expenses.

The Compound Amount Factor

THE compound amount factor for end-of-year compounding of interest is defined by $(1 + i)^n$ where i is the rate of interest and n is time in years. The compound amount factor for continuous compounding of interest is given by e^{in} where e is a constant and is equal to 2.718; i, interest rate; and n, time in years.

The curves in Fig. 12-1 illustrate the compound amount factor up to 25 years for 3 and 6 per cent interest rates. The solid curves are for continuous compounding of interest. The dashed curve is for end-of-year compounding of interest at 6 per cent. The compound amount factors for continuous and end-of-year compounding of interest at the rate of 3 per cent are practically identical.

The Present Worth Factor

The reciprocal of the compound amount factor, $(1 + i)^{-n}$ or e^{-in}, is called the present worth factor. The present value of future production is equal to the rate of production times a present worth factor. For example, present value in M.c.f.'s per M.c.f., or barrels per barrel, of gross production 10 years hence discounted at the nominal rate of 4 per cent has the following values:

Interest compounded	Present worth factor
Annually	0.67556
Semiannually	0.67297
Quarterly	0.67165
Continuously	0.67032

The first three values may be obtained from a set of interest tables. The present worth factor for continuous compounding of interest is equal to e^{-in}. The value of this factor may be obtained from handbooks containing exponential forms.

Producing rates do not decline once or twice annually. They decline continuously. It is much easier to apply continuously compounded present worth factors to production than annual or semiannual present worth factors. For this reason, continuous interest factors will be used.

A barrel, or an M.c.f., of production producible at any time n years hence is equal to 1 bbl., or 1 M.c.f., times the present worth factor e^{-in}. The value of production at zero time, that is, at the time the production is brought to the surface, is unity or 100 per cent. But the value now, n years before the time of production, is one times the present worth factor e^{-in}.

The curves in Fig. 12-2 illustrate the present value per unit of production n years hence discounted at the

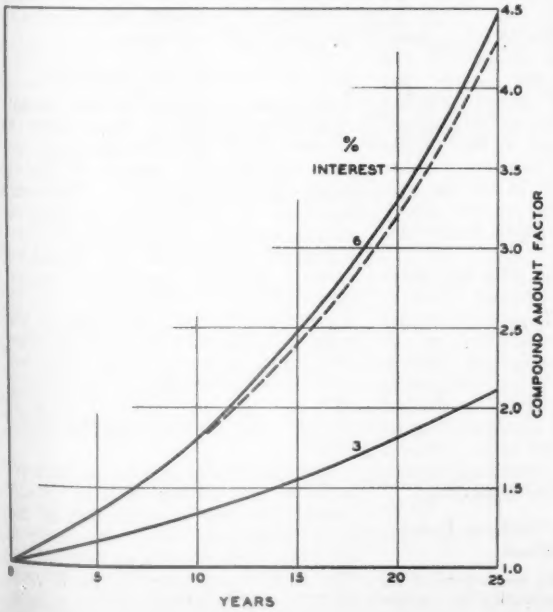


Fig. 12-1—(Left) Compound amount factor vs. time; solid curves for continuous compounding of 3 or 6 per cent interest rate; dashed curve for end-of-year compounding of 6 per cent interest rate

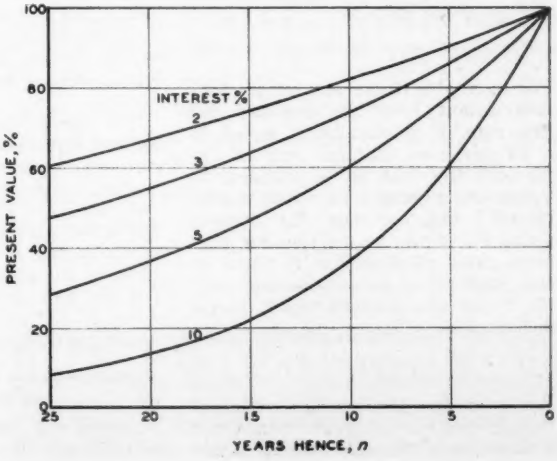
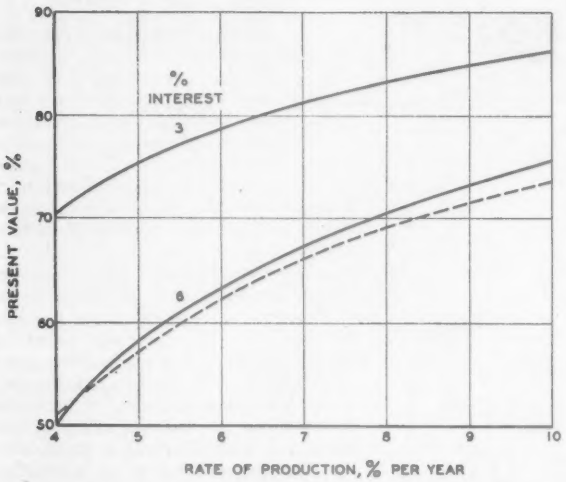


Fig. 12-2—(Below) Present value of production vs. time and interest rate; interest is compounded continuously

*Production consultant, Houston.



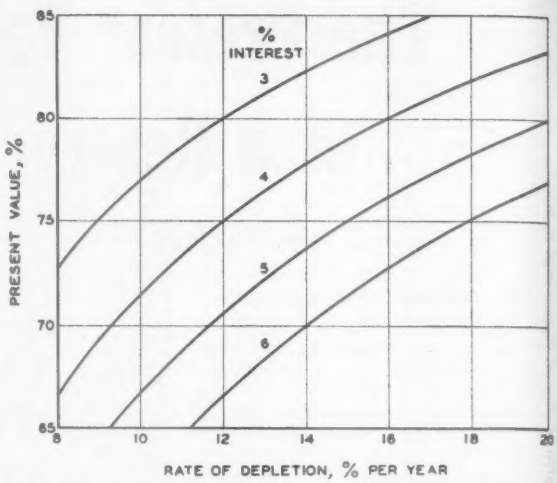


Fig. 12-3—(Left) Present value for uniform rates of production; rate of production in per cent per year of initial reserve; present value in per cent of the reserve recoverable at uniform rates of production; dashed curve is for annual compounding of 6 per cent interest; solid curves for continuous compounding of interest. Fig. 12-4—(Right) Present value for uniform rates of depletion; present value in per cent of the reserve recoverable at a uniform rate of depletion; present value is before investment, taxes, royalty and operating expenses

rate i. For example, oil and gas producible 20 years hence have the following values:

Interest rate, %	2	3	5	10
M.c.f.'s/M.c.f.	Present value			
or barrels/barrel	0.67	0.549	0.368	0.135

The Present Value of Production

Consider a uniform rate of production. The rate of production n years hence will be the same as today. Let the rate of production be Q M.c.f.'s, or barrels, per day. The present value P_0 of this producing rate is refined by

$$P_0 = Qe^{-in} \qquad (1)$$

For example, the present value of 1,000 bbl. per day producible 10 years hence and discounted at 3 per cent is equal to $1{,}000(e^{-0.3})$ or 740.8 bbl. Similarly, a 100-million-per-day gas producing rate 10 years hence is now worth 74 million feet.

Consider a uniform rate of depletion R. The rate of production n years hence (see Part 11 of this series) is given by

$$Q = Re^{-Rn} \qquad (2)$$

For example, if the rate of production is now 1,000 bbl. per day and this rate of production is equal to a 10 per cent uniform rate of depletion; the rate of production 10 years hence would be e^{-1} or 0.3678 or 367.8 bbl. per day. The present value P_0 of the production for uniform rates of depletion is equal to the product of the producing rate Re^{-Rn} and the present worth factor e^{-in}, that is,

$$P_0 = Re^{-(R+i)n} \qquad (3)$$

For example, the present value of the production 10 years hence for a uniform 10 per cent rate of depletion discounted at 3 per cent is (367.8) (0.74) or 252 bbl. provided the rate of production is now 1,000 bbl. per day.

Present Value for Uniform Rates of Production

Denote the reserve recoverable at uniform rates of production by unity. For example, 20, 40, or 60 per cent of an initial reserve may be recoverable before production starts declining. Denote this reserve by unity. Then, on the assumption that this reserve is recoverable at approximate uniform rates of production, its present value P is defined by

$$P = \frac{Q}{i}(1 - e^{-i/Q}) \qquad (4)$$

where Q is a uniform or average rate of production in M.c.f.'s per M.c.f., or barrels per barrel, per year of the reserve recoverable before production starts declining. Equation 4 is derived in the appendix to this article. The present value P. is in M.c.f.'s per M.c.f., or barrels per barrel, of the reserve recoverable before production starts declining.

The curves in Fig. 12-3 are solutions of Equation 4. Present value, in per cent of reserve, is plotted against uniform rates of production in per cent per year of an initial reserve. The solid curves are for continuous compounding of interest. The dashed curve is for annual compounding of a 6 per cent interest rate. Present value is before investments, taxes, royalty, and operating expenses.

Present Value for Uniform Rates of Depletion

Denote the reserve recoverable at uniform rates of depletion by unity. Let R be a uniform rate of depletion. Then (see the appendix to this article) the present value P of reserve is defined by

$$P = \frac{R}{R + i} \qquad (5)$$

where R is in M.c.f.'s per M.c.f., or barrels per barrel, per year of reserve and P is in M.c.f.'s per M.c.f., or barrels per barrel, of the reserve recoverable at uniform rates of depletion.

The curves in Fig. 12-4 are solutions of Equation 5. Present value, in per cent of reserve, is plotted against uniform rates of depletion. The data are for continuous compounding of interest. Present value is before investments, taxes, royalty and operating expenses.

A Natural Gas Reservoir

Fifty per cent of a 400-billion natural gas reserve is recoverable at the rate of 8 per cent annually before production starts declining. After production starts declining, the rate of production is likely to be proportional to reserve. Estimate the present value of the 400-billion reserve for a 3 per cent interest rate.

Solution: In this example, 50 per cent of an initial reserve is recoverable at a uniform 8 per cent per year rate of production. From Fig. 12-3, the present value is 0.832 on 50 per cent or 0.416 of the initial reserve.

The life of the reserve at uniform rates of production is 50/8 or 6.25 years. The rate of depletion at the time production starts declining is 8/0.5 or 16 per cent per year. From Fig. 12-4, the present value is 0.842 of 50 per cent of the initial reserve

WOOD RIVER

QUALITY PRODUCTS AVAILABLE TO THE INDEPENDENT JOBBER

ETHYL and all grades of leaded and unleaded gasoline
TRACTOR FUEL DIESEL FUEL
ASPHALT KEROSENE
Numbers 1, 2, 3, DOMESTIC FUEL OIL
RANGE OIL INDUSTRIAL FUEL OIL

SALES OFFICES:
HARTFORD, ILLINOIS P. O. Box 145
Phone Wood River 4-4374
ST. PAUL, MINNESOTA 1700 Stewart Avenue
Phone De Soto 5533

HOME OFFICE:
WICHITA, KANSAS

WOOD RIVER OIL AND REFINING COMPANY, INC.

•BASIC HEADQUARTERS for OIL WELL Chemicals!

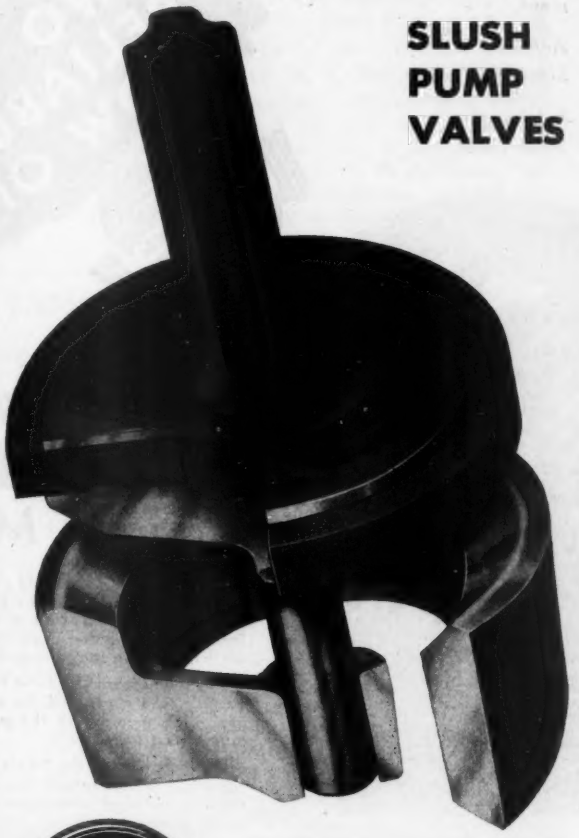
Valosa Phosphates (All types)
Quebracho
Barium Sulphate
Silicates
Special Gums

• *Inquire direct or through your dealer.*

THOMPSON-HAYWARD CHEMICAL CO.
HOUSTON NEW ORLEANS DALLAS
TULSA SAN ANTONIO OKLAHOMA CITY
WICHITA

RED DEVIL

SLUSH PUMP VALVES



RED DEVIL OIL WELL SPECIALTIES BEST BY TEST

MAXIMUM SERVICE
MINIMUM UPKEEP COST

RED DEVIL Slush Pump Valves with REVERSIBLE INSERTS provide MAXIMUM service at MINIMUM expense on high-pressure drilling jobs. They SEAL TIGHT and stay on the job longer because they're scientifically engineered to SEAL RIGHT and made of highest-quality materials to insure longest service for tough jobs.

As shown above, RED DEVIL SLUSH PUMP VALVES are designed for utmost simplicity—having only five parts with each part made of high quality materials to assure longest service. Nothing complicated—no weak parts to cause break downs and expensive delays.

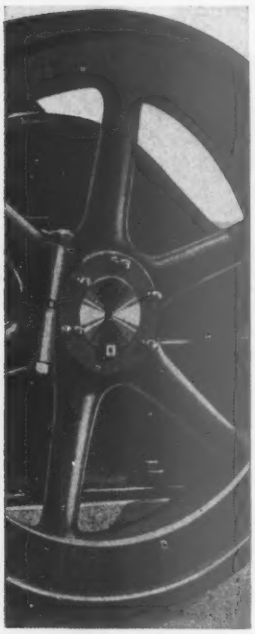
Available for ANY SIZE or MAKE of Pump.
See Composite Catalog or write for Bulletin No. 107-A.

OIL WELL MANUFACTURING CORP.
6000 SO. ALAMEDA ST., LOS ANGELES, CALIF.
CABLE ADDRESS "OWMCO"

The World's Standard of Quality in Oil Field Equipment - - -

Acme — Since 1900

Pattin — Since 1888



ACME DRILLING & FISHING TOOLS

PATTIN BROS. DIVISION of Acme Fishing Tool Co. Founded 1888 — Pioneers Afloat

TWO "OLD RELIABLES" NOW ONE

Pattin *Ruggedness* — a Tradition Gone Modern

There are many "performing examples" of Pattin RUGGEDNESS in the Oil Country that are now serving ***well*** their ***second generation*** of owners. Thus it is established fact that Pattin Engines, Powers and Compressors are built for ***life-long*** dependable, economical service.

It would be amazing to know the revolutions those "Old Timers" have made and the equivalent in "road mileage" — compared with the ***potential*** of present-day ***high-speed*** units.

While adhering to the Pattin ***tradition*** — that RUGGEDNESS is the ***safest*** foundation for enduring efficient, economical performance in oil field equipment — improvements in design and operational refinements have kept pace through the years.

Guided by long experience and a firm conviction that comparative slow speed, single cylinder, heavy-duty engines ***deliver*** far more ***power,*** at much less cost, over the long pull — meaning greater hole footage drilled or volume of oil lifted — we continue to ***specialize*** in them.

(Note: Supporting our "stick-to-itivness" and prediction is the new trend toward slower speed units — as revealed by our recent visits to principal fields.)

PATTIN BROS. ENGINES
POWERS — COMPRESSORS

"GLUTTONS for Life-Long Punishment"

Write TODAY for New Catalog

Wear More — "Drilmor"

Acme Drilling Jars: Famous since 1900 for their longer wear, as measured by footage of hole drilled. Forged ***only*** of correct jar steel, meeting Acme's rigid specifications for ***proper*** heat treatment — by long-seasoned craftsmen especially skilled in jar making. Furnished in either Rein Welded type (Fig. 107) or "Drilmor" Weldless.

Fig. 107
See Acme — Composite Catalog.

ACME FISHING TOOL CO.
PARKERSBURG, W. VA.

PATTIN BROS. DIV.
of Acme Fishing Tool Co.
MARIETTA, OHIO

Export Office: 19 Rector St., New York 6, N. Y.

ALTEN
Louisiana Pattern
CASING HEAD
with Split Gland and Seat

ONE OF OVER 300 ALTEN OIL FIELD PRODUCTS

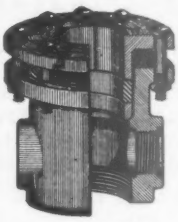


Fig. A-100

Fig. A-101

See Composite Catalog for complete list or write us for catalog.

ALTEN'S
FOUNDRY and MACHINE WORKS
Established 1889 . . . . . Lancaster, Ohio

EXPORT OFFICE: 342 Madison Ave., New York 17, New York

TEXAS OFFICE: 46 San Jacinto St., Houston 1, Texas

Leading Supply Stores Carry All Alten Oil Field Equipment

ST. LOUIS SNAPSHOTS

HE CAN RELAX...
HE HAS A RESERVATION AT THE HOTEL

Mayfair
EIGHTH AND ST. CHARLES

or 0.421 of the reserve. This present value is relative to 6.25 years hence. From Fig. 12-2, the corresponding present value relative to now is 0.816 of 0.421 or 0.343.

Therefore, the present value of the reserve is 0.343 plus 0.416 or 0.759 or 303.6 billion feet of gas. This present value is before investments, taxes, royalty and operating expenses.

An Oil Reservoir

Thirty per cent of a 40-million-barrel oil reserve is recoverable at the rate of 6 per cent annually before production starts declining. After production starts declining, the rate of production is likely to be proportional to reserve. Estimate the present value of the 40-million-barrel reserve for a 3 per cent interest rate.

Solution: In this example, 30 per cent of an initial reserve is recoverable at a uniform 6 per cent per year rate of production. From Fig. 12-3, the present value is 0.786 on 30 per cent or 0.236 of the initial reserve.

The life of the reserve at uniform rates of production is 30/6 or 5 years. The rate of depletion at the time production starts declining is 6/0.7 or 8.6 per cent per year. From Fig. 12-4, the present value is 0.742 of 70 per cent of the reserve or 0.519 of the initial reserve. This present value is relative to 5 years hence. From Fig. 12-2, the corresponding present value relative to now is 0.824 of 0.519 or 0.428.

Therefore, the present value of the reserve is 0.428 plus 0.236 or 0.664 or 26,560,000 bbl. of oil. This present value is before investments, taxes, royalty, and operating expenses.

Appendix to Article 12

The present value of the reserve recoverable at uniform rates of production may be derived as follows: The present value of production at any time n is given by

$$P_o = Qe^{-in}$$

The present value of the cumulative recovery P_c at any time n is defined by

$$P_c = Q\int e^{-in}dn$$

from which

$$P_c = \frac{Q}{i}(1 - e^{-in})$$

But the life of a reserve recoverable at uniform rates of production is equal to 1/Q. Substitution of 1/Q for n in the foregoing expression gives Equation 4.

The present value of the reserve recoverable at uniform rates of depletion may be derived as follows: The sum of the products of producing rates Re^{-Rn} and present worth factors e^{-in} is equal to the present value of the cumulative recovery at any time n, that is,

$$P_c = R\int e^{-(R+i)n}dn$$

from which

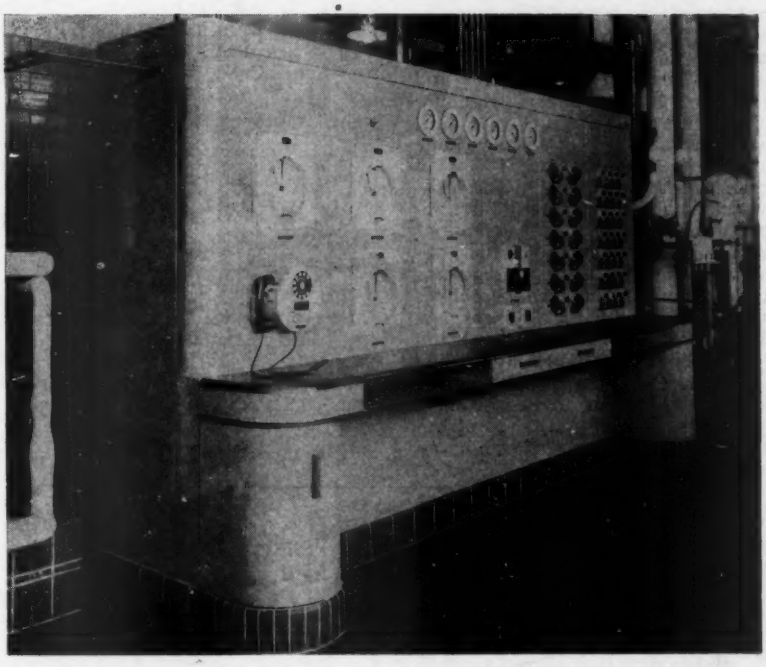
$$P_c = \frac{R}{R+i}[1 - e^{-(R+i)n}]$$

But, even if we were to continue producing indefinitely, the value of the expression within the brackets could not exceed unity. Therefore, the present value of the reserve recoverable at uniform rates of depletion cannot exceed the value defined by Equation 5.

G. W. Larson, chief engineer, will continue to supervise the engineering division at the Sugar Creek, Mo., refinery of Standard Oil Co. (Indiana), which has been enlarged to include two departments, the design and the plant engineering. The design department will be supervised by **W. L. Mathews,** assistant chief engineer, assisted by **I. Erickson,** head engineer of design. The plant-engineering department will be supervised by **D. A. Harris,** assistant chief engineer, assisted by **G. R. Gray,** acting head engineer of inspection.

EXPLOSION RESISTING

Refinery Control Panels



Switchboards and Instrument Boards

Illustrated is a Control Panel installed in one of the major oil companies pilot plants. This panel covers a large number of electric heaters with variable voltage transformers, pilot lights and circuit breakers, all in explosion resisting enclosure and operated from front of panel. Unit type construction allows extreme flexibility of installation to meet individual requirements completely wired, reducing to a minimum field installation. Steel construction throughout with excellent hand rubbed finish. Available with desk as part of unit, adaptable to circular panel arrangements and individual modifications as desired to meet any requirement.

Lighting Panels

Control and Transfer Switches

NELSON ELECTRIC MANUFACTURING CO.

217 North Detroit TULSA, OKLAHOMA Telephone 2-5131

MANUFACTURERS OF:

Explosion Resisting Motor Controls
Junction Boxes and Enclosures
Circuit Breakers and Lighting Panels
Oil Field Motor Controls
Automatic Pipe Line Sampling Devices
Cathodic Protection Equipment
Switchboards
Instrument and Control Panels
Unit Substations

QUESTIONS on TECHNOLOGY

by W. L. Nelson
Consulting Engineer

Superiority of Desulfurized Gasolines

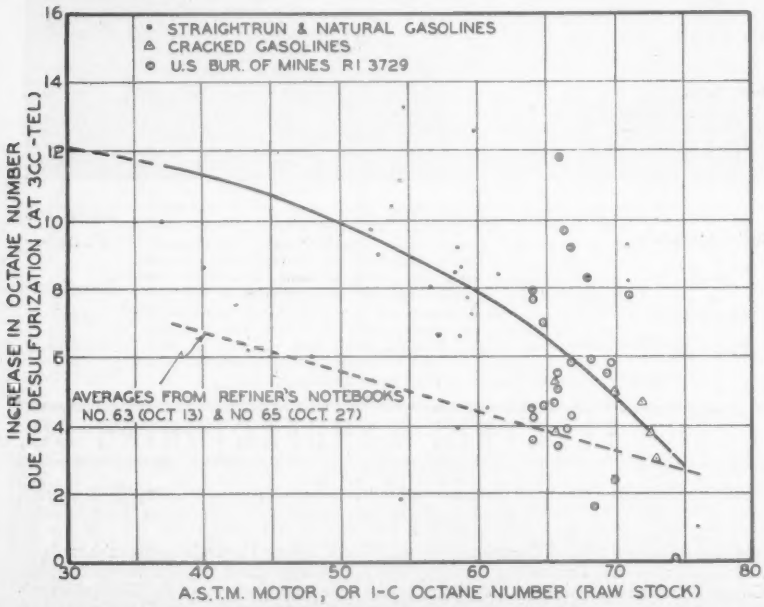
In connection with your Refiner's Notebook we were much interested in the improvement of lead susceptibility by catalytic desulfurization. However, we are not sure that we properly interpret your tabulations because these show too great an increase in the lead susceptibility for the desulfurized gasolines. Will you please discuss this for us?—R.C.H.

The figure on this page shows actual laboratory tests of the improvement in octane number caused by catalytic desulfurization (see Questions on Technology, October 6 and October 13, 1945). The average improvements shown as a solid line, ranges from about 3 at a clear octane number of 75, up to about 11 for an octane number of 40. Note, however, that a few samples did not respond well, giving improvements of only 1 or 2. The dotted line was obtained from the average data for straight-run and natural gasolines published in Refiner's Notebook No. 63, October 13, 1945 (untreated) and No. 65, October 27, 1945 (desulfurized). This relationship (the dotted line) would appear to be the most trustworthy because it is based on all available data on undesulfurized gasolines rather than particular gasolines that may have been selected for desulfurization and which may have been particularly amenable to treatment by desulfurization. Nevertheless, the dotted line shows an increase in octane number due to desulfurization of 3 to 7 units octane number, and this is not a negligible improvement. It is noteworthy that cracked gasolines are improved by about the same amount as straight-run gasolines of the same clear octane number. Circle points were computed from Bureau of Mines data (Guthrie & Simmons, R. I. 3729, Effects of Desulfurization on the Lead Susceptibility of Distillates from Some Crude Oils from Texas, New Mexico, and Oklahoma).

The improvement can be more forcefully emphasized by a direct comparison of octane number, as in the tabulation that follows, because it shows the relatively high octane numbers that can be attained by desulfurization. Data were taken from Refiner's Notebooks Nos. 63 and 65.

Clear Oct. number	Octane number: 3 cc. TEL Raw	3 cc. TEL Desul.	4 cc. TEL Raw	4 cc. TEL Desul.
40	62.9	69.4	66.2	72.0
50	67.9	75.5	72.4	77.9
60	77.4	81.7	79.4	83.8
70	85.1	88.3	86.6	89.9

Thus, ordinary stocks (50-60 clear octane number) can be brought to leaded octane numbers of 75 to 80 if they are desulfurized whereas gasolines of 60-70 clear octane number are required if desulfurization is not practiced. The gaining of octane number by catalytic desulfurization and the use of lead, is relatively cheap compared with catalytic cracking processes.



Increase in octane number (using TEL) of catalytically desulfurized gasolines as compared with untreated gasolines

Flash Point of Crude Oils

We understand that crude oils that have a flash point over 30° F. are handled differently by the railroad companies. What is the flash point of typical crude oils?—G. A. C.

Flash point is not a test that is determined on most crude oils. Nevertheless, here are two determinations which were obtained by chilling the crude oil and then allowing it to warm to room temperature.

Crude oil—	A.P.I.	Per cent off by a Hempel distillation: At 122° F.	At 167° F.	At 212° F.	Flash point (O.C.)
Oklahoma	38.8	2.0	3.8	5.3	10° F.
West Texas	38.2	3.3	4.0	5.5	10° F.

Unfortunately these two oils are much alike.

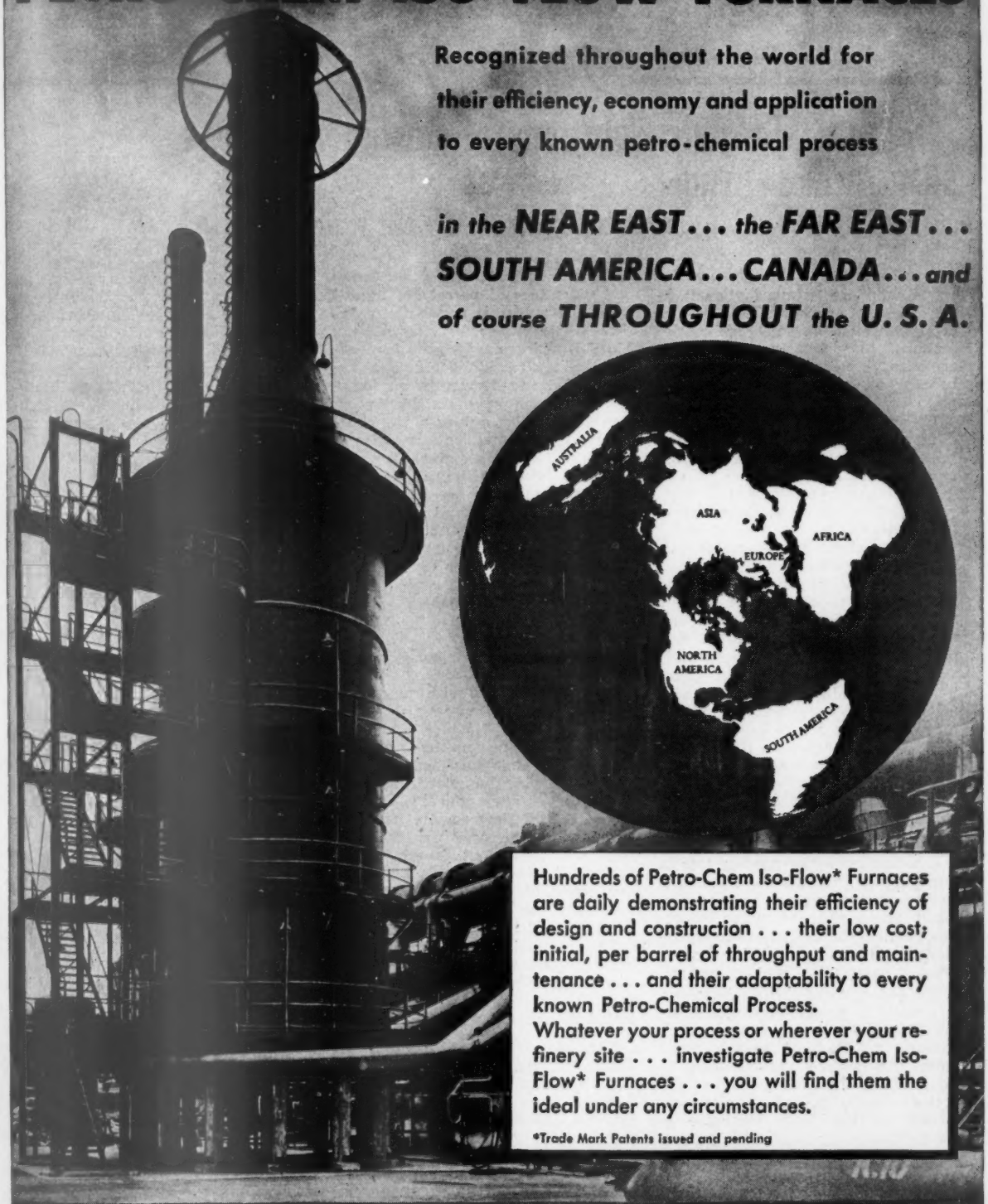
In the September 1, 1938, issue of The Oil and Gas Journal (page 42, "Flash Points Useful . . ."), a correlation of flash point versus average boiling point between 0 and 10 per cent distilled was presented. Although the correlations given there were not based on data on crude oils, the above experimental data were checked against the equation of flash point of poorly fractionated or raw stocks:

$$F = 0.57\ B - 110$$

in which, F is approximate flash point and B is the average boiling point of the first 10 per cent of the material. The average boiling point of the above crude oils is below 212° F., perhaps 205° F., by which the above formula shows a flash point of about 7° F.

Obviously, there are so many variables that a formula cannot be exact. A loss may occur during distillation, some crude oils have been weathered and others have been "plugged" with natural gasoline. Any or all of these factors tend to introduce errors into any formula. Nevertheless, in a most general way, crude oils which boil at a temperature (0-10 per cent) higher than 260° F. should have a flash point higher than 30° F.

PETRO-CHEM ISO-FLOW* FURNACES



Recognized throughout the world for their efficiency, economy and application to every known petro-chemical process

in the NEAR EAST... the FAR EAST... SOUTH AMERICA... CANADA... and of course THROUGHOUT the U. S. A.

Hundreds of Petro-Chem Iso-Flow* Furnaces are daily demonstrating their efficiency of design and construction . . . their low cost; initial, per barrel of throughput and maintenance . . . and their adaptability to every known Petro-Chemical Process.
Whatever your process or wherever your refinery site . . . investigate Petro-Chem Iso-Flow* Furnaces . . . you will find them the ideal under any circumstances.

*Trade Mark Patents issued and pending

PETRO-CHEM DEVELOPMENT CO., INC.

120 EAST 41st STREET, NEW YORK 17, N. Y.

REPRESENTATIVES

Bethlehem Supply Co., Tulsa, Houston · Petroleum Equipment Co., Los Angeles · D. D. Foster Co., Pittsburgh · Faville-Levally Corp., Chicago

PRACTICAL PETROLEUM ENGINEERING

Fluid Flow

Graphic Solutions of Design Problems

5—Resistance of Fittings

by Paul Buthod and B. W. Whiteley

Enlargement and contraction losses and viscosities of petroleum liquids were the subjects discussed in Article 4, November 10 issue. Chart, Fig. 4-1, which may be used for finding the contraction coefficient, accompanied the discussion on losses due to line changes. In the discussion on viscosity, values of the characterization factors for a number of crudes and stocks are given. A chart, Fig. 4-2, from which viscosities, at different temperatures for various crudes and stocks may be predicted, is included with the discussion. This chart which is based upon reliably correlated data will be found useful when measured viscosities of a crude or stock are not available.

As fluids flow through circular pipes, there is invariably an energy loss which results in a pressure drop between the inlet and outlet sections. Likewise, any gain in energy from external sources, such as by a pump, results in an increase in pressure.

The various terms which affect the difference in pressure between the inlet and outlet sections of the pipe may be listed as follows:

1. Difference in elevation.
2. Gain or loss of kinetic energy of the fluid.
3. Mechanical work added or taken from the fluid.
4. Friction losses in the fluid system, consisting of friction loss in the straight pipe, enlargement and contraction losses, and resistance of fittings, meters, orifice plates, etc.

For incompressible fluids, these items are handled in the form of a mechanical energy balance, which may be written as:

$$p_1 - p_2 = \Delta p_f - \rho\,(y_1 - y_2) - \rho\left(\frac{u_1^2 - u_2^2}{2g}\right) - \rho w_o \qquad (1)$$

Calculation of the friction loss in straight pipe presents no serious difficulty. Enlargement and contraction losses are usually of minor importance unless the design of the equipment requires an allowable pressure drop of extremely small magnitude.

The resistance of fittings, however, is usually of major importance, especially in the design of processing equipment. Friction losses incurred from this source may extend to points past the fitting due to increased turbulence in the downstream section. The resistance to flow, afforded by these fittings, may be calculated in terms of an equivalent length of straight pipe. Considerable data are available for computing the equivalent length of fittings for the flow of water and air. Within the viscous flow region experiments show that the resistance is primarily a function of the Reynolds number. However, in the turbulent region of flow, the resistance of fittings appears to be independent of the Reynolds number for a given pipe diameter. Consequently the experimental values for equivalent lengths may be used with reasonable accuracy for such viscous fluids as oils.

The equivalent length of various types of fittings has been plotted against the pipe diameter in Fig. 5-1. These values are applicable only to the turbulent flow region. In order to calculate the pressure loss in a line, the equivalent length of all fittings in the system is added to the length of straight pipe and the pressure drop is computed as outlined previously.

The method for calculating the various items which affect the pressure difference between the inlet and outlet sections of a pipe, is illustrated by the following example:

Example 1.—An absorption oil (38° A.P.I. gravity, K = 11.8, flowing temperature 80° F.) is to be pumped from an accumulator tank into the top of an absorber at the rate of 5,000 gal. per hour. The accumulator is maintained at 2 psig. pressure and the oil level is at an average height of 20 ft. above the ground level. The pump is to be placed at ground level. The suction line consists of 2-in. standard pipe, connected to the bottom of the accumulator. This suction line is 30 ft. long and contains two 90° ells and two gate valves.

The pump discharges into the absorber through a 2-in. standard line which is 220 ft. long and contains eight 90° ells, five tees (side outlet) and one gate valve. The absorber is maintained at 150 psig. The oil line enters the absorber at a point 50 ft. above ground level.

Calculate the theoretical horsepower necessary to pump the oil.

Solution.—The sources of friction loss in the system consist of the resistance of the fittings, loss through the pipe and a contraction loss from the accumulator tank into the 2-in. suction line.

The resistance of the fittings is calculated as equivalent length of straight pipe. Referring to Fig. 5-1:

Number	Fitting	Equivalent length in ft.
10	90° ells	41
5	Tees (side outlet)	52
3	Gate valves	5
Total		98

Since there is 250 ft. of straight pipe in the system, the total length of the line is 348 ft.

The flow rate is 5,000 ÷ 42 = 119 bbl. per hour.

The kinematic viscosity of the absorption oil at 80° F. is approximately 3.2 centistokes (Fig. 4-1).

The gravity of the oil at 80° F. is 39.6° A.P.I. Using a kinematic viscosity of 3.2, a pipe diameter of 2 in. and a flow rate of 119 bbl. per hour, the Reynolds number is found to be 40,000 (Fig. 1-1). The value of ϵ/d is 0.0009 (Fig. 2-1). The value of the friction factor "f" is 0.0245 (Fig. 2-2). Using a friction factor of 0.0245, 2-in. pipe size, 119 bbl. per hour and A.P.I. gravity of 39.6°, the pressure drop due to friction is found to be 64 psi. per 1,000 ft. of line (Fig. 3-1).

The friction loss through the line and fittings is:

$$64 \times 348/1{,}000 = 22.3 \text{ psi.}$$

The contraction loss is computed as follows:

The velocity of oil in the 2-in. pipe is:

$$\frac{5{,}000 \text{ gal./hr.} \times 231 \text{ in.}^3/\text{gal.}}{3{,}600 \text{ sec./hr.} \times 3.355 \text{ in}^2 \times 12 \text{ in./ft.}} = 7.97 \text{ ft./sec.}$$

The velocity in the accumulator

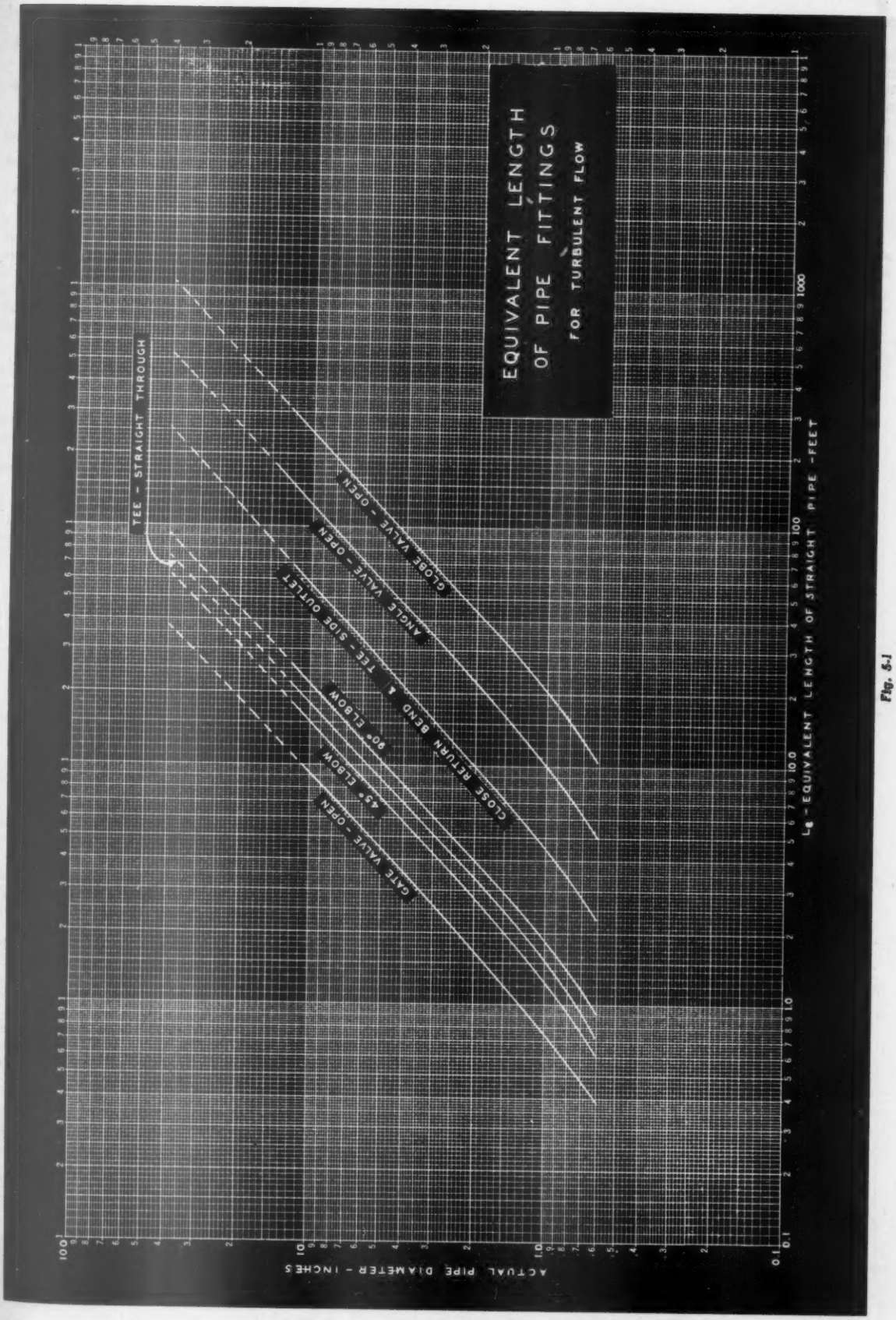

EQUIVALENT LENGTH
OF PIPE FITTINGS
FOR TURBULENT FLOW
TEE - STRAIGHT THROUGH
GLOBE VALVE - OPEN
ANGLE VALVE - OPEN
TEE - SIDE OUTLET
CLOSE RETURN BEND
90° ELBOW
45° ELBOW
GATE VALVE - OPEN
ACTUAL PIPE DIAMETER - INCHES
Le - EQUIVALENT LENGTH OF STRAIGHT PIPE - FEET

Fig. 5-1

tank is practically zero.

Referring to the equation and curve for contraction losses in Article 4 of this series, the value of the cross-sectional area ratio is practically zero so that the constant "C", is 0.00336. The pressure drop due to contraction is:

$$\Delta P_c = Csu^2 = 0.00336 \times 0.843 \times 7.97^2$$

$$= 0.18 \text{ psi.}$$

The total friction loss due to straight pipe, fittings and contraction is:

$$22.3 + 0.18 = 22.5 \text{ psi.}$$

In order to determine the horsepower to be supplied by the pump, it is necessary to determine the other items which make up the energy balance equation. This equation may be rewritten in the form:

$$\rho w_o = \Delta p_f - \rho(y_1 - y_2) - (p_1 - p_2) - \frac{\rho(u_1^2 - u_2^2)}{2g}$$

In the above equation the "ρw_o" term represents the increase in pressure to be supplied by the pump or in other words, it is the difference in pressure (lb. per sq. ft.) between the suction and discharge ends of the pump.

Substituting in the above equation:

$$\rho w_o = 22.5 \times 144 - (20 - 50) \times 62.4 \times 0.843 - 144 \times (2 - 150) - \frac{62.4 \times 0.843}{2 \times 32.2}(0 - 7.97^2)$$

$$\rho w_o = 26{,}170 \text{ lb./ft.}^2 \text{ or } 181.9 \text{ lb./in.}^2$$

At a flow rate of 5,000 gal. per hour the theoretical horsepower required to pump the fluid is:

$$\text{H.P.} = \frac{PV}{33{,}000} = \frac{26{,}170 \times 5{,}000}{33{,}000 \times 60 \times 7.48} = 8.8$$

Notation:

- C = coefficient for contraction loss
- g = acceleration due to gravity—32.2 ft./sec.^{2}
- K = characterization factor of oil
- L_e = equivalent length of fittings—ft.
- Δp_f = pressure drop due to friction—lb./ft.^{2}
- ΔP_f = pressure drop due to friction—psi.
- ΔP_c = pressure drop due to contraction—psi.
- p = pressure—lb./sq. in.
- P = pressure—psi.
- s = specific gravity.
- u = linear velocity, ft./sec.
- V = flow rate—cu. ft./sec.
- y = elevation head—ft.
- w_o = shaft work, ft. lb./lb.
- ρ = density, lb./cu. ft.

Subscripts 1 and 2 = points within flow system.

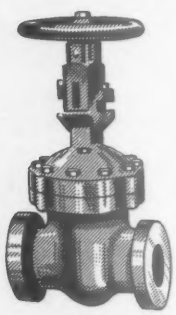
References

1. Dodge, R. A., and Thompson, M. J., "Fluid Mechanics," McGraw-Hill Book Co., New York (1937).
2. Badger and McCabe, "Elements of Chemical Engineering," McGraw-Hill Book Co., New York (1936).

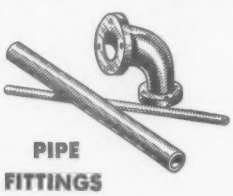
Maj. Charles Edmonson, Owensboro, Ky., formerly a scout and landman for The Texas Co. and now with the Army of Occupation in Salsburg, Austria, was cited for heroism in leading a crossing of the Po River in Italy and has been awarded the Bronze Star and Oak Leaf Cluster. He was wounded in the exploit, and the Purple Heart was conferred on him. Wounded again in another action, he received that decoration a second time.

Charles B. Hunt, of the military unit, U. S. Geological Survey, Washington, D. C., spoke on "Geology as Applied to Military Intelligence" before the Houston Geological Society on October 31. The society had as guest speaker on November 5 **Dr. John T. Lonsdale,** director of the Bureau of Economic Geology. Dr. Lonsdale's topic was "Postwar Program for the Bureau of Economic Geology."

all YOUR refinery needs

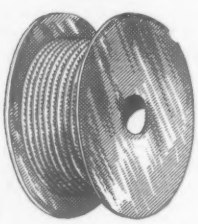


VALVES



PIPE FITTINGS

WIRECO WIRE ROPE



as close as your telephone

L.D. 410

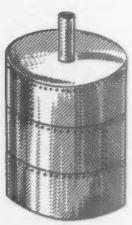
Dial

TULSA 5-3175

FOR

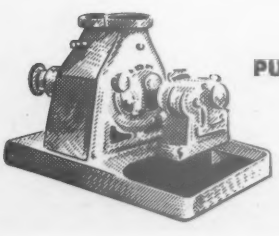
Complete Stocks and Prompt Delivery

- Refinery Equipment, New and Reconditioned
- Distributors for Wireco Wire Rope
- Exclusive Distributors for Security Valves and Fittings
- Featuring Savings on Reconditioned Materials and Equipment



TANKS

When you need a valve, a pump, pipe, fittings or tanks, you want delivery in a hurry, so DON'T WASTE TIME! Just reach for the telephone for any of your refinery needs, and we will soon have your equipment on its way. No need to shop around at a dozen different places when Refinery Equipment has everything you need. Investigate our ONE-STOP service for all your refinery supplies. It's as close and convenient as your telephone.



PUMPS

Refinery Equipment, Inc.

Subsidiary: Souken-Galamba Corp.

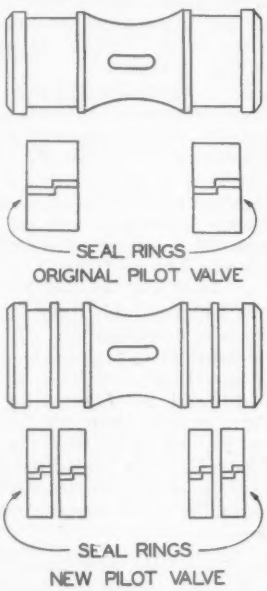
UNION AVENUE AT 21st STREET

TULSA, OKLAHOMA

PLANT PRACTICES

Improved Pilot-Valve Arrangement for Hot Oil Pumps

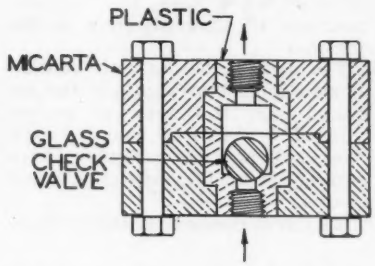
IN the operation of hot-oil pumps, such as the Wilson-Synder types, sometimes the outside ring flange of the cast-iron piston cracks off, which stops the pump and requires extensive repairs on occasion. Instead of the one wide seal ring on each end



of the pilot valve of the pump, two narrow rings have been installed, a plan which offers more safety against incapacitation of the pump in case of such breakage. The use of two rings also effects a much better seal, reducing the amount of steam blow-by and improving the main steam-valve action. (Idea submitted by P. E. Schroeter.)

Glass Check Valve in Corrosive Service

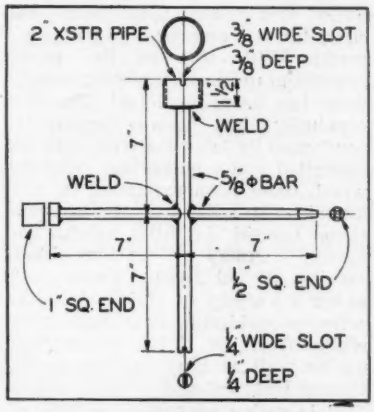
IN some modern operations such as in isomerization of hydrocarbons the use of anhydrous hydrochloric (muriatic) acid introduces problems of corrosion. In one instance in a column converted to fractionation of light hydrocarbons containing hydrochloric acid, duriron check valves were installed where the acid is present. In time these valves showed severe corrosion so that frequent replacement and repair was necessary. Breakage of these valves during repair or replacement occurred frequently. In the absence of less corrodable valves such as Hastelloy-B, a glass-and-plastic valve was shop



designed and two were installed. The design is shown in the drawing. The valve is in two parts, fastened together by bolts; the body is of Micarta, cut with a cylindrical recess which aids in making the body fluid-tight. This body is lined with plastic, forming the valve chamber; in this chamber the glass ball valve is inserted before the valve body is assembled. The ends of the plastic lining-chamber may be threaded to connect into the line. The life of the valve has not been determined, but present indications are that it will last for several years, no corrosion damage having been found up to the present, in continuous service. (Idea submitted by M. F. Miles.)

Four-Way Wrench for Barrel Bungs

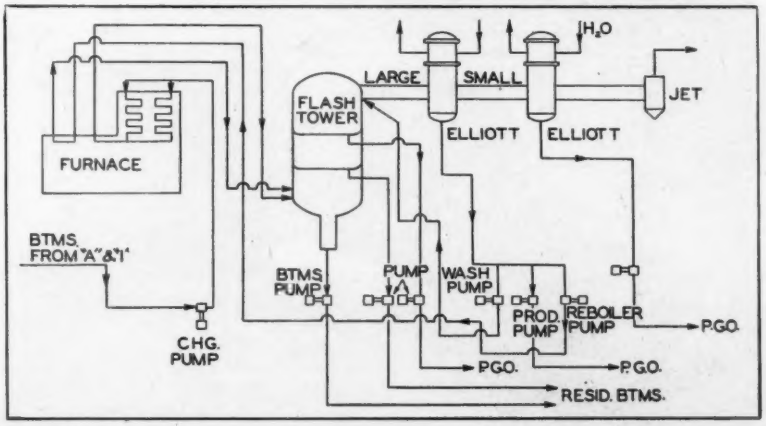
THIS is a simple wrench with four separate ends which includes the different sizes of fittings to handle all bungs of oil barrels. It may be



made up by welding the individual arms at a central point with ends fitted to the different bungs' dimensions. (Idea submitted by A. H. Witt.)

Crude Bottoms as Reboiler Heat Medium

THE primary purpose of stripping crude or other heavy bottoms is to recover the maximum yield of the highest-priced product; gas oil is of more market or refinery value than heavy crude bottoms. To recover more gas oil from crude bottoms it was arranged to pass the bottoms from a pair of fractionating batteries through a reboiler section of a flash coil heater in place of another stream formerly sent to that reboiler. As a result, this crude bottoms shows a 5 per cent higher yield of gas oil than that which was achieved by the earlier operation. (Idea submitted by L. H. Hanson, flash-coil operator.)



(The ideas described here are used in the Baytown, Tex., refinery of Humble Oil & Refining Co.)

Unitized Equipment for Pipe-Line Gathering Service

by William Law*

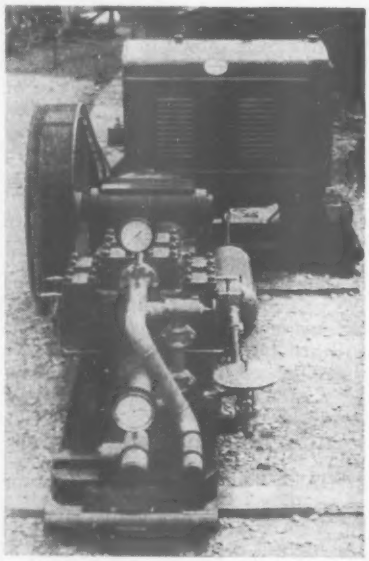
THE need for reliable equipment for field gathering has been evident throughout our experience with this branch of pipe-line operation. Reliability rather than high efficiency, low first cost, or any other factor has been more desired for the objective of making a profit. With this as the prime requisite, unitized pumping equipment has been developed. The first conclusion has been subsequently confirmed by later experience in the operation of gathering systems which have been expanded to now include 364 units at 304 field stations located in hill, harsh, and swamp country of various kinds serving 60 oil fields. These units pump a variety of fluids including refinery residuum, sour and sweet crudes from 18° A.P.I. gravity and up, as well as sour and sweet distillates and water.

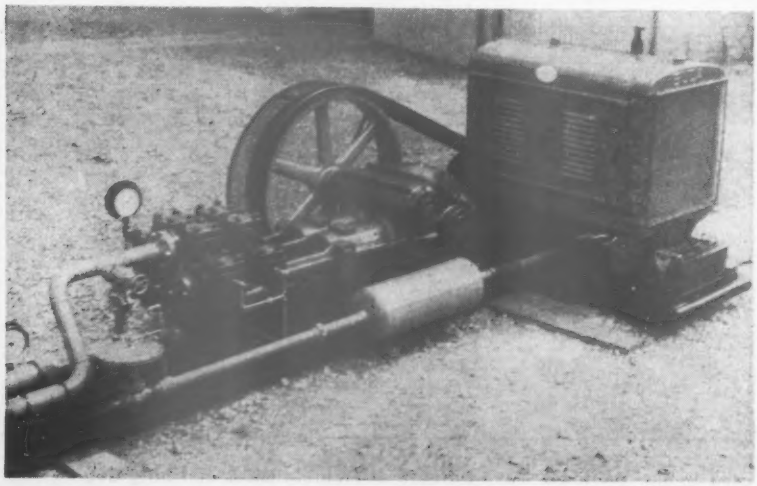
Field-gathering service makes unusual demands upon equipment and at the same time imposes certain definite restrictions. Reliability and continuity of operation can be somewhat assured in certain other fields of operation by means of skilled attendance and massive or extra equipment, but here in gathering-line service equipment must be light and portable. Constant skilled attendance is obviously out of the question.

The field-gathering unit consists of an engine and pump of the required size and type of proven worth. It is compactly mounted upon steel skids and has necessary auxiliaries, attachments, instruments, and guards.

To attain desired reliability there is provision for interchangeability of the component parts of any given size of unit. This interchangeability is not dependent upon the make of engine or pump. The unit is designed to provide for the interchange of various makes of engines and pumps. We have 135 units made up of four different makes of pumps and three different makes of engines; in these units all engines and pumps can be interchanged. This characteristic of unitized equipment eliminates entire dependence upon one manufacturer of equipment, allows purchasing on a competitive basis, and permits minimum provision for replacement parts. This feature, during the last few war years, has contributed greatly to our ability to maintain continuous service in old fields while we have been expanding operations.

*Master mechanic, southern division, Interstate Pipe Line Co.





Views of pumping unit containing a duplex pump driven by a six-cylinder high-speed engine equipped to burn either natural gas or gasoline, mounted on skids especially designed for gathering-line service

Unitized equipment is built for our requirements in three sizes. The smallest is capable of pumping from 50 bbl. per hour at 1,200 psi. to 137 bbl. per hour at 400 psi.; this is used where production is small or where conditions demand a unit for each location. The intermediate size is capable of pumping from 57 bbl. per hour at 1,000 psi. to 242 bbl. per hour at 340 psi.; this type of unit has the widest application. The large unit is built in two sizes: one handles from 51 bbl. per hour at 1,400 psi. to 238 bbl. per hour at 575 psi.; the other pumps from 148 bbl. per hour at 925 psi. to 550 bbl. per hour at 270 psi.; such units are used where large quantities are available or for smaller trunk lines or booster stations.

The horizontal duplex, piston-type, enclosed power-end pump has been adopted since it handles a wide range of viscosities; it is readily adaptable and is comparatively trouble free. The six-cylinder industrial-type, high-speed engine, equipped to burn either natural gas or gasoline, has been adopted because it is compact and light; there is little vibration for the horsepower developed; natural gas is usually available at field locations; V-belt drive is used.

While the nature of field-gathering service indicates the size and type of equipment for a given installation, unfortunately it does not point out the particular pieces of equipment or makes, which when combined, will give the most dependable unit. Knowledge which guides in determining these matters has been gained by actual and costly experience.

Reliability is usually associated with a conservative rating. But imposed restrictions force a compromise. Best performance is secured by selecting equipment on a reasonably conservative basis and allowing the degree of variation from

"Centerville" Is Putting In a LAYNE WATER SYSTEM

"Centervilles" throughout the nation are rapidly graduating from town-pump villages. Their growth and stability as cities of lovely homes, fine business houses and progressive citizens has called for the installation of a modern water system. Officials of "Centerville" are beginning right—taking no chances on water supply failure—expensive operation, or short life of wells and pumps. They are putting in a Layne Well Water System. Investigation has shown "Centerville's" officials that a Layne Well Water System is easily within their means and is a sound and profitable investment.

These same kind of Layne Well Water Systems and Layne Vertical Turbine Pumps are serving the nation's largest cities—the greatest industries, biggest railroads, and the most extensive irrigation projects. Layne water producing equipment enjoys the reputation of being the world's best—and that reputation is constantly growing stronger and stronger.

Layne offers fine and always dependable Well Water System counsel with no obligation. For further facts, catalogs, etc., address Layne & Bowler, Inc., General Offices, Memphis 8, Tenn.

HIGHEST EFFICIENCY

Layne Vertical Turbine Pumps are now available in sizes to produce from 40 to 16,000 gallons of water per minute. Their high efficiency saves hundreds of dollars on power cost per year.

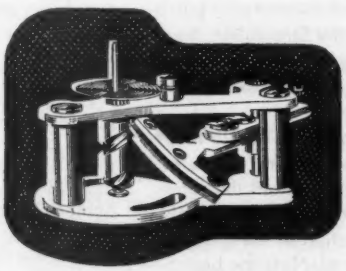
AFFILIATED COMPANIES: Layne-Arkansas Co., Stuttgart, Ark. * Layne-Atlantic Co., Norfolk, Va. * Layne-Central Co., Memphis, Tenn. * Layne-Northern Co., Mishawaka, Ind. * Layne-Louisiana Co., Lake Charles, La. * Louisiana Well Co., Monroe, La. * Layne-New York Co., New York City * Layne-Northwest Co., Milwaukee, Wis. * Layne-Ohio Co., Columbus, Ohio * Layne-Texas Co., Houston, Texas * Layne-Western Co., Kansas City, Mo. * Layne-Western Co. of Minnesota, Minneapolis, Minn. * International Water Supply Ltd., London, Ontario, Canada * Layne-Hispano Americana, S. A., Mexico, D. F.

LAYNE

WELL WATER SYSTEMS
VERTICAL TURBINE PUMPS

AMERICAN CHAIN & CABLE CO., INC. has acquired the business of the Certified Gauge & Instrument Corp.

The Certified pressure gage, which has proved to be so revolutionary because of the Helicoid movement, will hereafter be manufactured by American Chain & Cable. For the sake of clarity, this precision instrument will be known as the Helicoid Gage.



The Helicoid movement is used exclusively in Helicoid Gages

The outstanding performance of the Helicoid Gage will be even further improved by the engineering ability and experience of American Chain & Cable.

If you are not now using Helicoid Gages and if you desire to reduce your gage maintenance cost, order them the next time.

See your nearest Distributor.

ACCO

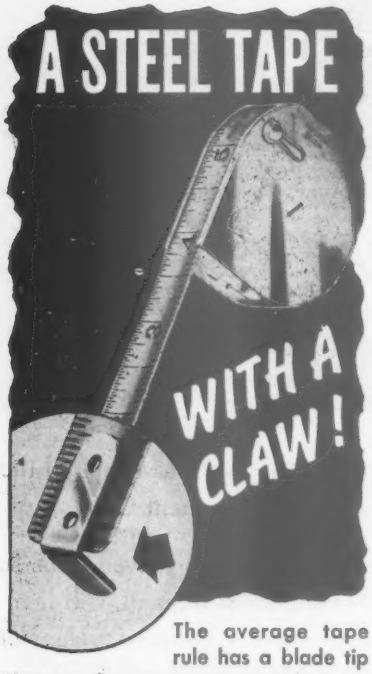
34-18 Northern Boulevard, Long Island City 1, N. Y. • Bridgeport, Conn.

HELICOID GAGE DIVISION
AMERICAN CHAIN & CABLE

TRADE MARK

In Business for Your Safety

11-CG-1



The average tape rule has a blade tip that merely serves to prevent the tape from sliding into the case. Theoretically it is supposed to catch and hold the edge of the object measured—but it doesn't. The tip of the Streamline, however, is 7/16" long—a real claw that actually serves the purpose for which it was designed.

But this unusual tip is just one of STREAMLINE's outstanding features. Note the Lever Lock, to hold the reading when making inside measurements. Note the smooth action of the blade in its frictionless channel. Note the beautiful chrome case finish and simple construction, making it easy to insert spare blade when needed.

STREAMLINE has proved to precision-conscious craftsmen, mechanics and engineers that it's just as quick—just as easy to be 100% accurate.

$2.65 each Complete with spare blade

For fast action, use the coupon!

MASTER
WOOD AND TAPE RULES

Master Rule Mfg. Co., Inc., Dept. S-11
815 East 136th St., New York 54, N. Y.
Branch P.O. Box 1587, Oakland, Cal.

Please send me:

- ☐ STREAMLINE 6 ft. size ($2.00 ea.)
- ☐ STREAMLINE 8 ft. size ($2.25 ea.)
- ☐ 8 ft. replaceable blade (70c ea.)
- ☐ 6 ft. replaceable blade (65c ea.)

Name_____

Address_____

City_____ State_____

such a rating to be determined by actual knowledge of the ability of the part.

The following data give a breakdown of a typical unit into its component parts, the method applied in making a selection, description of details and the reason why it is used:

Skids.—Skids are made of H-beam sections. Such sections are used since they provide a rigid foundation and have a large bearing area. The skids for the small unit are in one piece accommodating both engine and pump. The intermediate and large units have separate skids for engine and pump; these are connected with a bolted connection for ease of handling and efficiency of transportation. Skids for both engine and pump are designed for easy sliding; they have lugs at the end to prevent slipping of a winch line; there is a jacking pad to provide safety in handling.

Pumps.—Manufacturer's rating is usually accepted in regard to frame load and allowable fluid and pressure with 10 ft. per minute as the maximum piston speed. We have found that manufacturer's rating on pumps is usually reasonable. In addition to comparative construction features, consideration is given to suction characteristics and the attitude of the manufacturer in regard to supplying repair parts.

Relief and bypass assembly.—The purpose of this particular equipment is to protect the pump from overload due to excessive pressure and due to excessive stress from connected lines. The relief and bypass assembly consists of short sections of the suction and discharge piping anchored securely to a skid. These lines are connected through an angle-spring-loaded relief valve. Openings are provided in the discharge section for a pressure gage; there are openings in the suction section for a pressure-vacuum gage and also for a line to an outside sump tank.

Bleeder and drain piping.—All bleeder valves are connected to a common line leading to an outside sump tank. Drain lines are also connected to this common line, providing for cleanliness and safety.

Gas regulator and reservoir assembly.—This consists of a house-type regulator and small reservoir used when running on natural gas. It is mounted on a pump skid.

V-belt drives.—All drives are calculated with a liberal factor of safety. The drive for each size of unit is standardized as to belt size and length, engine sheave, and pump sheave.

Engines.—No particular preference is shown for any one make of engine. We assume that all manufacturers make good engines, but we know from experience that certain sizes of each are better for meeting our needs. The engine must produce the required horsepower calculated on the basis of 70 lb. brake mean effective pressure and piston speed is not to exceed 1,000 ft. per minute. Consideration is given to construction details, past performance in this kind of service, and to the distribution and availability of repair parts. Engine horsepower requirements are usually set at from 5 per cent to 10 per cent more than input horsepower of the corresponding pump calculated at 85 per cent efficiency.

Pumping-unit engines are equipped with natural gas-gasoline carburetors to better assure operation and to provide for being free of dependence on one type of fuel. Engines are also equipped with electric starting and battery ignition. Electric starting is required for safety. Distribution ignition offers ease of repair and serves as a preventative for battery overcharge.

Other equipment on the engines is as follows: (a) Safety controls to protect the engine from excessive water temperature and from low oil pressure; (b) oil-pressure gage; (c) manifold vacuum gage indicating the load carried by the engine and also reflecting the condition or adjustments of the engine; (d) top lubricators to give upper-cylinder lubrication when burning dry natural gas; (e) adequate air and lubricating oil filters are standard equipment.

Guards.—Guards are provided for V-belt drive and fan; where necessary guards are used to protect rotating engine shafts.

From the nature of these details it can be seen that our intent is not to create a robot but to build sound equipment which may be operated intelligently.

This type of equipment has been proven in service. The best means of measuring its economy is to determine ability to give continuous service. The first cost of gathering-line equipment, adequately designed with necessary attachments for protection of equipment and proper operation exceeds by very little the cost of poorly designed equipment.

Jack P. Robbins, recently discharged from the Army, has joined the production department of Houston Natural Gas Corp. as district engineer of the Alice, Tex., area. Robbins served 4 years in the Army, including an assignment in the Aleutians as a captain in antiaircraft. Before entering service Robbins was a petroleum engineer with Wellington Oil Co. and The Texas Co. He holds a degree in petroleum engineering from Oklahoma University, class of 1937.

The Refiner's Notebook

A WEEKLY FEATURE OF THE OIL AND GAS JOURNAL

Conditions for Maximum Topping-Tower Capacity

THERE are three principal ways of increasing the capacity of an existing topping tower making changes in its operation or by adding only to it exterior connections:

1. Operate at maximum allowable pressure.
2. Utilize side reflux.
3. Produce a minimum overhead product.

In addition, a fourth method may be used on some towers. This method consists of drawing the distillate and gas oil very low in the tower thus leaving a large number of plates between distillate and the kerosene. When operated in such a manner the tower can be operated at overcapacities of 20 to 30 per cent because the kerosene and gasoline are so far away from the distillate plate that carryover or entrainment into the top of the tower is small. The distillate and gas oil so produced are not of prime quality.

Maximum pressure.—The capacity is not increased directly proportional to the increase in pressure, i.e., to double the pressure does not double the capacity. The increase is large enough to warrant consideration if the tower will stand the pressure and if the pipe still can provide the higher outlet temperature that is required. The increases are somewhat as shown in Table 1.

TABLE 1—EFFECT OF PRESSURE ON TOWER CAPACITY

Gas pressure psig.	Abs. press. psia.	% increase in capacity
0	14.7	..
2½	17.2	8
5	19.7	15
7½	22.2	22
10	24.7	28
15	29.7	40
20	34.7	52
30	44.7	72

The amount of liquid to be handled by the downcomers is greater and hence it is doubted that most towers can handle the 52 to 72 per cent extra capacity indicated for gage pressures of 20 and 30 lb. The downcomer sizes given in Refiner's Notebook No. 52, July 28, 1945, are not large enough for pressure towers.

TENTATIVE SCHEDULE

No. 65 Oct. 27, TEL Desulfurized Gasoline.
No. 66 Nov. 3, Thickness of Towers.
No. 67 Nov. 10, TEL Cracked Gasoline.
No. 68 Nov. 17, Maximum Tower Capacity.
No. 69 Nov. 24, Crude Exchangers.
No. 70 Dec. 1, Tower Inspection.
No. 71 Dec. 8, Approach in Exchangers.

Side reflux.—(See Refiner's Notebook, August 18, 1945). Normally the top of a tower must handle the largest volume of vapor and hence the use of side reflux to condense the (reflux) vapor before it gets to the top of the tower results in greater capacity. In addition to the increase in capacity due to side reflux, an increase in capacity can be gained by overloading the tower. This is possible when side reflux is employed because the overloading occurs at the lower plates of the tower where fractionation need not be good in order to produce salable gas oil and distillate. The degree of overloading that can be tolerated cannot be stated for all towers but the increase in capacity due to side reflux alone, is somewhat as indicated in Table 2,

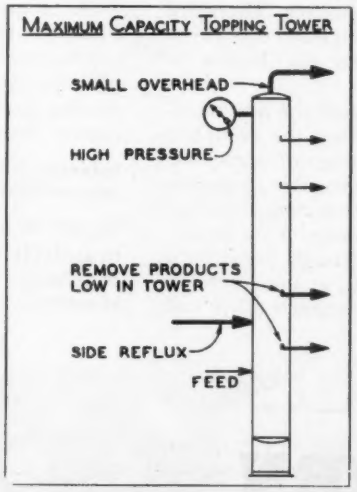


TABLE 2—INCREASE IN CAPACITY BY SIDE REFLUX

Side-reflux used at	Topping through distillate Per cent	Topping through gas oil Per cent
Kerosene plate	4	*1.7
Distillate plate	14	1.0
Gas oil plate	..	5.3
Plate at 75° F. below vaporizer temp.	11	11.0

*Decrease in capacity.

Side reflux is most effective if used at points low in the tower but the increase in capacity seldom exceeds 10-15 per cent.

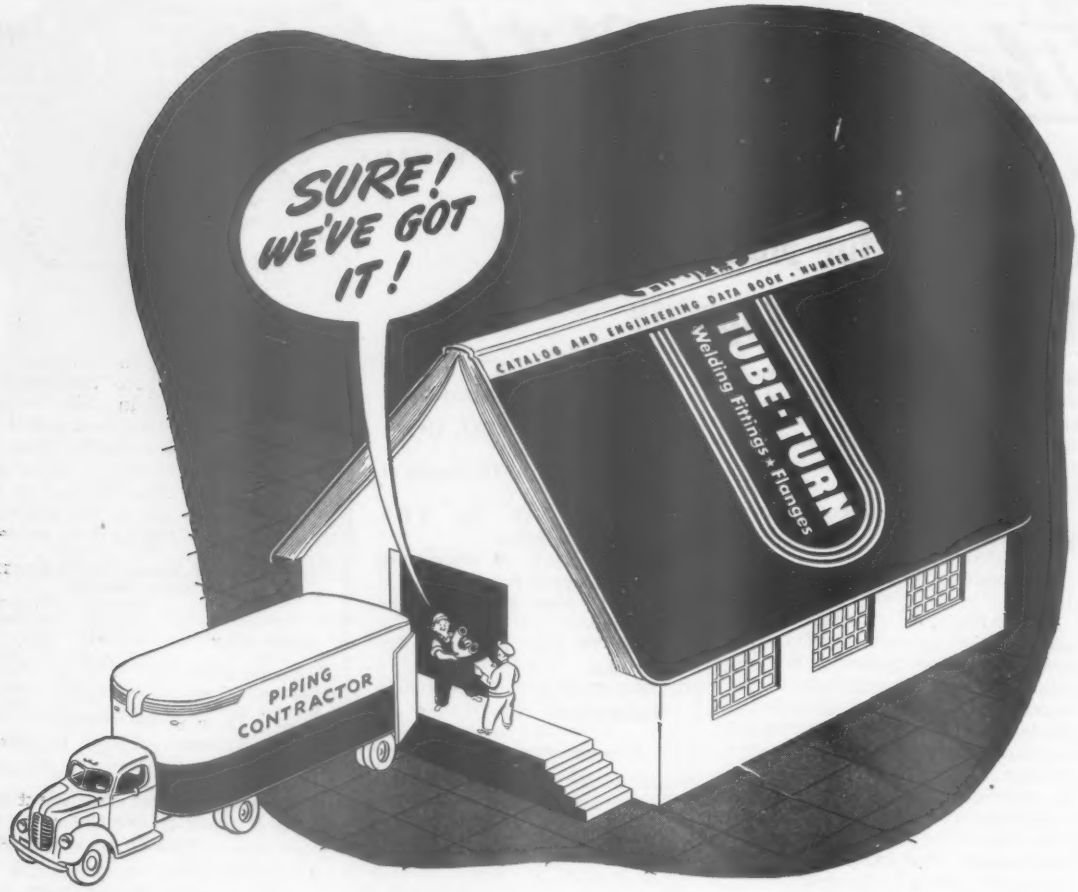
Theoretically the capacity of a topping tower would be about double if side reflux heat were removed at every tray but this would greatly reduce the fractionation and would probably not be worth while because of poor fractionation and because of the complications in operating the plant. The use of side reflux at even one place such as at the distillate or at the gas oil plate harms the fractionation of the gasoline and kerosene to some extent.

Minimum overhead.—The production of a minimum of overhead such as to make 10 per cent of very light gasoline rather than 30 per cent of regular gasoline increases the capacity somewhat as:

Amount of gasoline per cent	Amount of naphtha per cent	Per cent increase in capacity per cent
30	0	0
20	10	6
10	20	20

Although the amount of reflux required at the top of the tower increases as less and less material is taken overhead, the extra reflux is more than compensated for by the smaller amount of product that issues from the top.

No. 68 in a series by W. L. Nelson, professor of petroleum refinery engineering, University of Tulsa



There are 4000 reasons for specifying TUBE-TURN Welding Fittings

WHEN planning any piping installation, it saves time and money to be able to get all your welding fittings from one source. There are more than 4000 items in the complete Tube Turns line, available through selected distributors in every principal city.

Tube-Turn welding fittings were the *first* seamless welding fittings. In building the complete Tube Turns line to meet all welding fitting requirements over a long period of years, this organization has acquired a wealth of experience in solving all manner of piping problems. This experience is yours to command, through your Tube Turns distributor. Behind him, at your service, stand the nearest Tube Turns branch office and the vast resources of the home office and laboratories.

Get acquainted with your Tube Turns distributor. However large or complicated your requirements, he has the answers. Write today for your free copy of Tube Turns Catalog 111, containing 240 pages of up-to-date welding fittings information.

Selected Tube Turns distributors in every principal city are ready to serve you from their complete stocks.

TUBE TURNS (Inc.), Louisville 1, Kentucky. Branch Offices: New York, Chicago, Philadelphia, Pittsburgh, Cleveland, Dayton, Washington, D.C., Houston, San Francisco, Seattle, Los Angeles.

TUBE-TURN
TRADE MARK

THE COMPLETE LINE OF WELDING FITTINGS AND FLANGES

Tests for Acid Solubility; Spent Acid-Water

CHARACTER of calcareous rock: Most limestones were formed originally in ocean beds by deposition of shells of sea animals and plants such as brachipods, mollusca (oyster, etc.), corals, and crinoids. Dolomites were formed as a result of water containing magnesium salts acting on limestone, the magnesium replacing part of the calcium to form calcium magnesium carbonate. Thus limestones are mainly primary deposits while dolomites are secondary; however, there are exceptions. Some limestones contain crystals of calcite of a secondary nature, i.e., water percolating through a limestone takes a small amount into solution under certain chemical conditions. As the water containing the dissolved limestone flows farther into the rock, conditions may change, and the lime is redeposited in crystal form. These crystals are known as secondary calcite. Examples of this type are the stalactites (rock icicles in large caverns, such as Carlsbad). In the same manner, percolating water will often dissolve other slightly soluble substances such as silica, chert, and calcium sulfate (anhydrite, gypsum) which may be redeposited in limestones and dolomites.

Solubility. — Calcareous or limy rocks are seldom 100 per cent soluble in acid. The insoluble portion is usually made up of siliceous materials (sand, quartz, chert), calcium sulfate (either anhydrite or selenite), argillaceous material (clay, shale), or pyrites of iron.

There are three principal methods of determining solubility. These are briefly described:

1. The sample is accurately weighed and placed in an excess of acid. When the reaction is complete, the residue is washed, dried and weighed again. The difference between the weight of the sample and the weight of residue divided by the weight of the sample and multiplied by 100 equals the solubility percentage.

2. A quantity of the sample is placed in a graduated glass container. The volume of the sample is noted and an excess amount of acid is added. When the reaction is complete, the quantity of the sample that was dissolved is easily calculated. This is perhaps the simplest method of determining solubility.

3. The fastest, most accurate and most generally used method requires the measurement of the quantity of carbon dioxide gas evolved by the action of an excess quantity of 28 per cent acid on 1 gr. of the sample. This is accomplished by the use of a simple apparatus (Fig. 1). The quantity of CO_2 which is given off from 1 gr. of pure lime or dolomite is known or can be determined simply by running a sample of it with the apparatus. Hence, the quantity of gas evolved from the formation sample divided by the quantity evolved from the pure sample multiplied by 100 equals percentage lime or solubility. In the apparatus shown, the CO_2 displaces water from the storage bottle into the graduated cylinder, and the actual measurements are made of the volume of water so delivered.

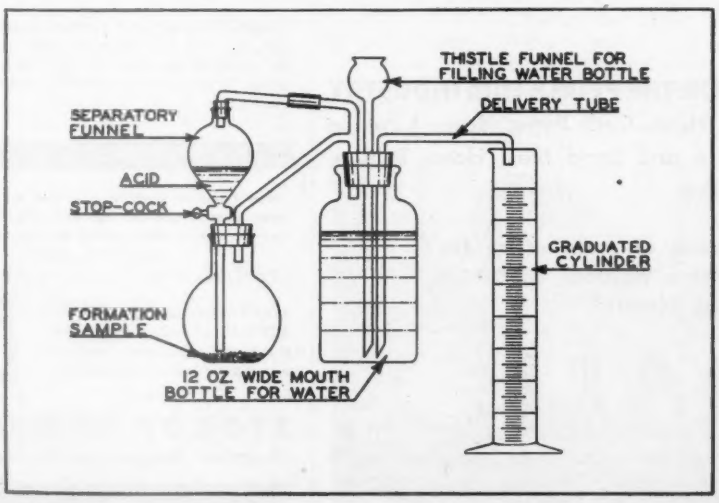


Fig. 1—Simple apparatus for testing per cent acid solubility of formations. Curves like Fig. 1 of Engineering Fundamentals No. 205, "Geology of Acidizing," (October 13, 1945, pp. 141-142) are obtained

Acid-water.—It is sometimes desirable when a well makes a small amount of water after treatment to determine whether or not the fluid is acid residue or brine. In most cases this may be learned by simple tests. If, however, an accurate determination is to be made, a sample should be sent to a chemical laboratory for analysis.

Acid-water usually has a bitter metallic taste that is distinguishable from a salt taste. This characteristic alone, to an experienced person, is usually a sufficient test.

The specific gravity of acid residue from 15 per cent HCl is about 1.18 (22° Baume) and, as a rule oil-well brines are considerably less. Hence, if the water is tested with a hydrometer and has a specific gravity of less than this reading, it is either brine, or acid residue diluted by brine or fresh water. If the specific gravity of the brine which the formation normally produces is known and compared with the reading, the results will yield a fair idea of whether or not the water is brine or a mixture of fresh water and acid residue. This comparison is particularly useful when fresh water was used as a loading material.

If a small quantity of concentrated sulfuric acid (sp. gr. 1.84) is added to a small sample of acid water, a heavy white precipitate of calcium sulfate is formed. This is an excellent qualitative determination when two tests are made simultaneously, one on the water in question and another on a sample of pure acid residue made by neutralizing a small quantity of treatment acid with some limestone from the well. This latter procedure is necessary because some well brines contain small amounts of calcium chloride which will form a slight precipitate when the test is applied. Care should be exercised in handling sulfuric acid because it may cause serious burns.

GOODALL "Newtype Cord" TANK CAR HOSE

The kinkproof, non-flattening construction of "Newtype Cord" Tank Car Hose cuts down unloading costs by providing a fast, unretarded flow at all times. The oilproof tube will match the long-life durability of the wire-reinforced carcass and tough, wear-resistant cover. Light weight, flexible, easy to handle. Reinforcing wire is anchored to couplings to carry off static. Sizes: 1½" to 4", inclusive.

OTHER GOODALL PRODUCTS FOR THE PETROLEUM INDUSTRY include Oil Suction and Discharge Hose; Curb Pump Hose; Airplane Refueling Hose; Steam, Water, Fire and Sand Blast Hose; Belting; Boots; Clothing; Packings and Gaskets.

Contact our nearest branch or main office for details and prices of these reliable GOODALL products. . . . "On the Job LONGER!"

GOODALL RUBBER COMPANY, INCORPORATED

THE GOODALL-WHITEHEAD COMPANIES

Philadelphia • Trenton • New York • Chicago
Pittsburgh • Boston • Los Angeles • San Francisco
Seattle • Salt Lake City • Houston

WE ARE PARTICIPANTS IN THE OWNERSHIP AND OPERATION OF NATIONAL SYNTHETIC RUBBER CORPORATION

Factory — Trenton, N. J.

Established 1870

Tube Borium Keeps 'em digging

DULL IN 3 DAYS
STILL SHARP AFTER 30 DAYS
STOODY TUBE BORIUM* KEEPS DITCHER TEETH SHARP ...ELIMINATES FREQUENT SHUT-DOWNS FOR TOOTH CHANGES...CUTS REPLACEMENT COSTS UP TO 75%

The two ditcher teeth pictured above were used on the same machine and operated under identical conditions.

The unprotected tooth at the top had to be sharpened every three days and was too short for further service after six sharpenings.

But the Borium-protected tooth at the bottom operated for 40 days and wore only ½". It was simply resharpened in the forge, retipped with Tube Borium, and put back on the ditcher for another 40 days' service.

Before the tooth was finally worn out, it had operated a total of 120 days!

Tube Borium makes such savings possible because the deposits represent the ultimate in wear resistance and the ability to cut hard earth formations.

*Stoody Tube Borium is supplied in rods of ⅛", 5/32", ¼" and 5/16" diameters and is available for either oxyacetylene or D.C. electric application. Prices and specifications are yours for the asking.

These tungsten carbide particles do not melt when tube is applied but are held in suspension in a mild steel matrix forming a deposit resembling coarse sandpaper.

Send for free booklet on TUBE BORIUM, showing sizes and styles of rods and recommended methods of application.

STOODY COMPANY

1138 West Slauson Ave., Whittier, Calif.

STOODY HARD-FACING ALLOYS
Stop wear . . Eliminate Repair

XUM

Natural Gas

Michigan-Wisconsin Plans Building of 1,216-Mile Line

WASHINGTON. — Federal Power Commission will hold a hearing January 8 on an application of Michigan-Wisconsin Pipe Line Co. for authority to build a natural-gas pipe line from the Hugoton field, Hansford County, Texas, to supply markets in the North Central states, and to acquire 140 miles of 26-in. gas line and appurtenances which are to be constructed by Michigan Consolidated Gas Co., both at an over-all cost of $70,000,000.

The project comprehends construction of 1,216 miles of 26-in. and 22-in. line, together with compressor stations having an aggregate of 104,600 hp., extending from the Hugoton field in a northeasterly direction to the Austin gas-storage field in Mecosta County, Michigan, and including lateral lines in Missouri, Iowa, Illinois and Wisconsin. The line to be purchased from Michigan Consolidated will extend from the Austin gas-storage field to a point near the city limits of Detroit, and other facilities including gas-storage facilities in the Austin and other gas fields. The facilities to be purchased are to be constructed by Michigan Consolidated and operated by Michigan-Wisconsin pending acquisition by the latter company.

The entire project is planned on a 4-year basis with about 1,076 miles of the main pipe line to be completed at a cost of $49,000,000 within the first year. The districts to be supplied include Milwaukee, Racine, Beloit, Janesville, and Madison, Wis.; Rock Island and Moline, Ill.; Des Moines, Davenport, Cedar Rapids, Ottumwa, Fort Dodge, and 36 smaller Iowa communities and Maryville, Mo.

Panhandle Eastern Patrons To Get $24,000,000 Refund

WASHINGTON. — Customers of Panhandle Eastern Pipe Line Co. in seven states will get refunds aggregating more than $24,000,000 under provisions of an order issued by Federal Power Commission. The amount represents charges adjudged excessive, collected since November 1942 in Missouri, Kansas, Texas, Michigan, Indiana, Ohio, and Illinois.

FPC accepted new schedules reducing the company's interstate wholesale rates by $5,110,000 compared with gross operating revenue in 1941. The commission said that because of increased sales since 1941, this will effect a reduction of $9,500,000 from 1944 billings.

The reduced rates are retroactive to November 1, 1942. Panhandle is a wholesale firm.

FPC Denies Rehearing in Wisconsin Southern Case

WASHINGTON. — Federal Power Commission has denied petitions filed by the interveners for rehearing and reconsideration of its order issued September 7, which enables Wisconsin Southern Gas Co. to serve its customers in southeastern Wisconsin with natural gas.

"No new facts," says the commission, "have been presented or alleged in the interveners' petitions which would justify a revision of the commission's order and opinion, and no principles of law are stated in the petitions which were not fully considered by the commission before it entered such order and opinion."

Those requesting rehearing include Wisconsin Railroad Association, Baltimore & Ohio Railroad Co., Wisconsin Coal Bureau, Inc., National Coal Association, and United Mine Workers of America.

The September 1945 order (1) directed Natural Gas Pipeline Co. of America to extend its transportation facilities to establish connection with those of Wisconsin Southern at the Illinois - Wisconsin state line near Genoa City, Wis., and to sell natural gas to the latter company for distribution to its customers in southeastern Wisconsin, and (2) authorized Wisconsin Southern to construct and operate a 4½-in. transmission main extending northward from this connection for 50,000 ft. to the company's existing facilities at Lake Geneva, Wis., with necessary appurtenances.

NEW DIVISION IS ESTABLISHED BY SUN OIL CO.

PHILADELPHIA.—A division of natural gas and natural gasoline is announced by Sun Oil Co., with James E. Pew as manager and Charles E. Webber assistant manager. The new division, which will function as a part of the production department, was created as a further development in a program for conservation and efficient utilization of gas resources.

Pew, formerly superintendent of Virginian Gasoline & Oil Co., Charleston, W. Va., served 45 months with Petroleum Administration for War in Washington, where he was director of the agency's natural gas and natural gasoline division. After leaving Massachusetts Institute of Technology, Pew joined United Natural Gas Co., Bradford, Pa., then moved to Pittsburgh where he did research on liquefied petroleum gases, natural gas and natural gasoline for Mellon Institute. He joined Hope Natural Gas Co. in 1926, resigning a few months later to go to Virginian Gasoline & Oil Co.

Webber, a graduate of Louisiana State University, was assistant director of PAW's natural gas and natural gasoline division at the time of his new appointment. Prior to his service with the Government's oil agency, which began in June 1942, he was associated with Humble Oil & Refining Co. in Houston, as a chemical engineer.

James E. Pew, right, and Charles E. Webber will direct Sun's new division

. . . for more efficient *Performance*

EQUIP YOUR PUMP WITH ALL MISSION PUMP PARTS . . . .

Put to work for you a team that has been proved by thousands of operators all over the world to speed up drilling by giving long trouble-free service.

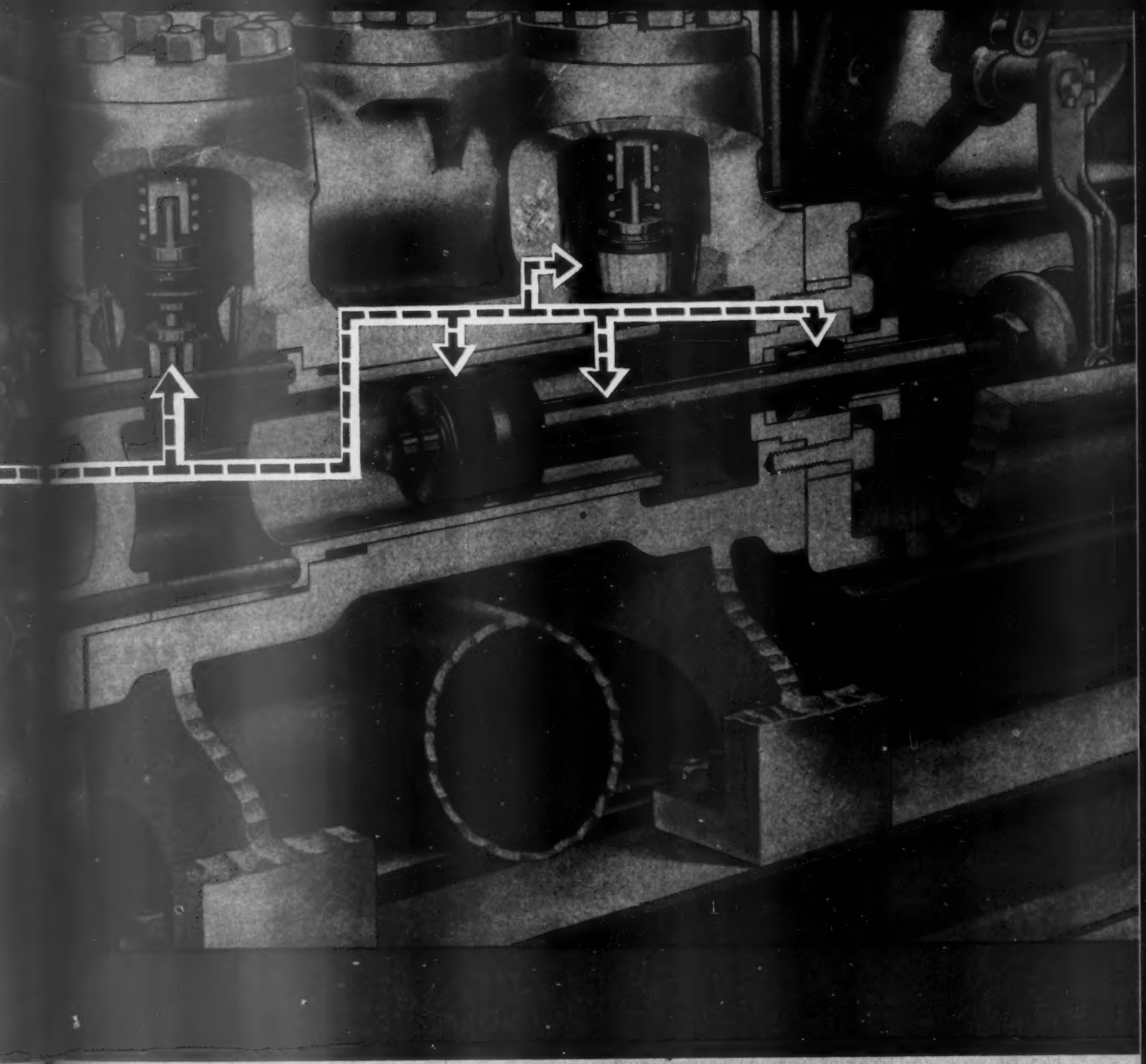
MISSION Replaceable Rubber PISTONS are made of tough, durable specially compounded rubber that runs efficiently for extremely long periods. And when they are finally worn, it's simple to install new rubbers on the old piston body at the rig, and you're ready for another long run.

MISSION PISTON RODS combine a core tensile strength of 120,000 pounds with exceptionally high ductility, giving maximum protection against breakage. The exceptional wearing qualities are due to the file-hard surface, plus a super-surfacing which gives 2 to 4 times the wear of ordinary rods.

MISSION Self Sealing GLAND PACKINGS automatically allow pump pressures to adjust packing to correct tightness, insuring a perfect seal on the pressure stroke, and free running on the return stroke—thus saving wear on both packing and rod.

MISSION SLUSH PUMP VALVES have a replaceable bushing which takes the wear instead of the larger, more expensive valve seat New, Compound-308 Inserts last at least twice as long as regular inserts.

XUM*



Use all Mission Pump parts. They work together for best all round performance.

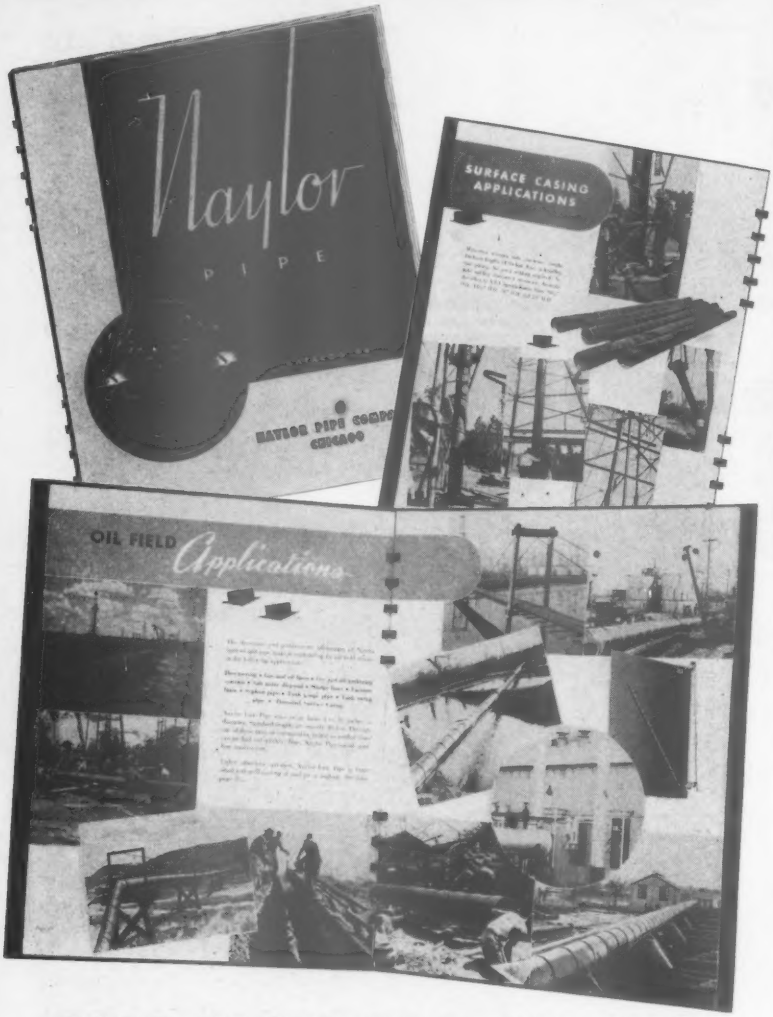
Mission

MANUFACTURING CO.

HUMBLE ROAD HOUSTON, TEXAS

EXPORT OFFICE, ROOM 1636 - 30 ROCKEFELLER PLAZA, NEW YORK 20, N. Y.

XUM



PIPE FACTS FOR OIL MEN

As a practical aid to oil men, the new Naylor Catalog provides a wealth of information on the use of light-weight pipe and Naylor surface casing in the oil fields. Included is such helpful data as connections and fabrication with new coupling methods which provide advantages never before possible. If you have not already received a registered copy of this valuable pipe guide, call our distributors or write us direct.

MID-CONTINENT SUPPLY COMPANY
Fort Worth, Texas and Branches
Exclusive distributors in Arkansas, Kansas, Louisiana, New Mexico, Oklahoma and Texas

NAYLOR PIPE COMPANY
1232 EAST 92nd STREET • CHICAGO 19, ILLINOIS
NEW YORK OFFICE: 350 Madison Avenue, New York 17, N. Y.

adeco...

NOZZLE TESTER

Keeps Diesel Engines Running Efficiently

To keep diesel engines operating at peak efficiency, this portable, precision-built Adeco Nozzle Tester is indispensable.

Light in weight yet built for heavy-duty service, it enables any mechanic to make quick accurate tests on injector opening pressure, spray pattern, etc., and detect stuck needle valves and leakage around valve seats. Tests both large and small injectors, on bench or engine, at pressures up to 10,000 p.s.i. Prevents costly delays and possible damage to engine.

Ideal for testing hydraulic devices.

•

Write for bulletin on this practical, low-cost unit.

TESTS FUEL INJECTORS AND HYDRAULIC DEVICES at Pressures up to 10,000 p.s.i.

ADECO
AIRCRAFT & DIESEL EQUIPMENT CORP.
DEPT. 7: 4411 N. RAVENSWOOD AVE.
CHICAGO 40, ILLINOIS

PIPE LINES

L. H. True Is Vice President Of Magnolia Pipe Line Co.

Election of L. H. True as vice president of Magnolia Pipe Line Co. has been announced by D. A. Little, president. Since 1938 True has been assistant manager of pipe lines; early in 1945 he was elected a member of the board of directors of the company.

L. H. TRUE

True was born at Belton, Tex., in 1903; more than half of his life has been spent in the service of the company. Since starting with the company in December 1922, he has been time keeper and material man in Arkansas and Oklahoma, gager at Corsicana, during the Powell boom, and also at Archer, Crane, and Wink, Tex. In 1931 he was chief gager and pipe-line scout in East Texas. Later he was superintendent of the Luling, Tex., district. In 1937 he was appointed general superintendent of Texas, Arkansas, and Louisiana. The following year he assumed his present responsibilities as assistant manager.

Pipe Arriving for All Great Lakes Spreads

Pipe is now arriving for all spreads engaged in the looping of the Great Lakes Pipe Line Co. system in sections from Barnsdall, Okla., to Sioux Falls, S. D. Gangs of all of the contractors engaged in the undertaking are now in the field and pipe-laying operations are progressing.

In connection with the expansion program, the Great Lakes company has contracted for 25 American Locomotive Co. 810-hp. turbocharged (Buchi system) engines.

Empire Southern Completes Lines

Empire Southern Gas Co. has completed 19 miles of 2-in. for 2,000 psi. operation and 41 miles of 8-in. The latter line was laid in 20 days. The job was contracted by H. C. Price Co., R. K. Shivel, superintendent. The project was located in Ector and Martin counties of West Texas, where the Empire Southern company connected the Shafter Lake field with its present system at a point near Big Spring, Tex.

Future of China Line Awaits Decisions

The India-China-Burma products pipe line is now filled with water, according to recent reports, and like the big inch and little big inch systems in the United States the great oriental line is waiting for action to determine its future status. There are possibilities that the China line may be traded to or sold to British interests. Under present conditions it is not regarded as having a commercial value although it has proved to be of vital importance in war.

The entire system with a total of 3,500 miles is said to consist of two 6-in. lines from Calcutta and Chitta-

SEND FOR THIS
New Book
ON
PROTECTIVE COATINGS

● This booklet describes Reilly Protective Coatings for pipe lines, storage tanks, towers, stacks, structural steel and other metal construction; also brick, cement and wood surfaces

REILLY TAR & CHEMICAL CORPORATION
Executive Offices: Merchants Bank Building
Indianapolis 4, Indiana
2513 South Damen Avenue
Chicago 8, Illinois
500 Fifth Avenue
New York 18, N. Y.

CRC

PIPE LINE CONSTRUCTION EQUIPMENT

CRUTCHER-ROLFS-CUMMINGS
Pipe Line Equipment and Materials
Houston, Texas, U. S. A.

ANDERSON BROTHERS
Pipe Line
Contractors and Engineers
707 NORTH DRENNAN
HOUSTON, TEXAS

. . . . . with MODERN, EFFICIENT EQUIPMENT . . . AND PLENTY OF IT!

above all
EXPERIENCE

Not just Contractors
but
PIPE LINE SPECIALISTS

WHEN YOU WANT
The Best
IN
PIPELINE CONSTRUCTION
OKLAHOMA CONTRACTING COMPANY
DALLAS TEXAS
SOUTH AMERICA
APARTADO 1085
CARACAS, VENEZUELA

McCORD
TYPE "C"
CHEMICAL MEASURING
PUMP

Extremely Accurate
DEPENDABLE
Accuracy of delivery in McCord chemical pumps is the result of a finely engineered design with a minimum number of parts. Dependability is insured because working parts are fully enclosed, protected from dirt and the elements. Specify McCord. For sale by National Supply Co.
Standard of the Oil Fields
McCORD
CORPORATION, DETROIT 11, MICH.

gong converging at Tinsukia in Assam; from Ledo to Burma two 4-in. lines and a 6-in. line; Kunming is reached by a 6-in. line.

Standard of Texas Lays Galveston Bay Line

Standard Oil Co. of Texas is laying 11 miles of 6-in. submarine line from barges across Galveston Bay which has been contracted by Austin Bridge Co. Pipe is coated with Somastic. The line is to be part of the system of Pasotex Pipe Line Co., a subsidiary of Standard Oil Co. of Texas.

WEP 20-In. River Bypass Is Removed

War Emergency Pipelines, Inc., has removed the 20-in. bypass line across the Rock Island Railroad bridge over the Arkansas River at Little Rock, Ark. This line was taken up by Williams Brothers Corp. which laid it in the spring of 1943 when the river crossing for the WEP 24-in. crude-oil line was damaged during a flood. Subsequently a 24-in. line was laid across the river with special provisions for insuring safety.

Humble Lays Line Near Abbeville, La.

Humble Oil & Refining Co. is laying 22 miles of 14-in. and 5 miles of 2½-in. and 3-in. lines near Abbeville, La. The work has been contracted by Associated Contractors & Engineers.

This contractor has also started operations for laying 15 miles of 16-in. for Interstate Natural Gas Co. near Port Barry, La. Somastic coating is being applied at both projects.

United Natural Connects Underground Storage

United Natural Gas Co. is completing an 8-in. line from the Lamont compressor station near Kane, Pa., to underground storage in the vicinity. This line will parallel another line of the same diameter to the underground storage reservoir.

Frannie Seeks Authority to Operate Two Pipe Lines

WASHINGTON. — Federal Power Commission held a hearing October 30 on the application of Frannie Gas Co. of Frannie, Wyo., for authority to operate its 3-in. 8.15-mile natural-gas transmission pipe line extending from the Polecat field in Park County, Wyoming, to a point on the Montana-Wyoming state line, and a 2-in. 4.74-mile line connecting with the 3-in. line, extending to the Yale Pipe Line Co.'s pumping station near Warren, Mont.

Tuscola-Mattoon Gas Line Is Being Laid

Central Illinois Public Service Co., Springfield, Ill., is laying a coated and wrapped 21-mile 6-in. line from Tuscola to Mattoon, Ill. Work has been contracted by Holdren Construction Co. Completion has been scheduled for December 1.

Motor Fuel Shipments By Pipe Line Decline

Deliveries of motor fuel by pipe lines in August totaled 25,826,000 bbl., a reduction of nearly 2,000,000 bbl. from the July aggregate of 27,865,000 bbl., the Bureau of Mines reported in its monthly petroleum statement last week. Motor-fuel deliveries by pipe lines in August 1944 totaled 25,853,000 bbl., the Bureau reported.

Increasing use of pipe lines for transportation of motor fuel from domestic refineries and terminals to consumer markets is shown, however, by comparing traffic for the first 8 months this year.

MOLE
Pipeline
Cleaner

For BETTER cleaning of
CRUDE LINES
PRODUCT LINES
NATURAL GAS LINES
FOR DETAILS WRITE
Pipeline Cleaners Co.
Fort Madison, Iowa

XUM

STOP ABRASION, SCORING of rods, shafts, liners, plungers

When shafts, rods, liners, or plungers score or wear, it's wasteful of time and it's costly to replace them. If such trouble comes from packing friction or packing deterioration, you can prevent a repetition of it by specifying RODPAK for repacking. RODPAK is the patented, guaranteed, non-friction, floating seal, long-lasting, moderate cost, highly efficient metallic packing. It's made to order to your specifications, when and how you want it. Prompt delivery. Simple and speedy to install; swift to fit, slow to wear. The patented construction is guaranteed to eliminate scoring of rods, shafts, etc. Friction co-efficient is extremely low (practically non-existent).

The two hydraulic rams illustrated above were operated identically for one year. The lower ram was packed with RODPAK; the upper ram was not.

SO . . . . . "PACK UP YOUR TROUBLES"

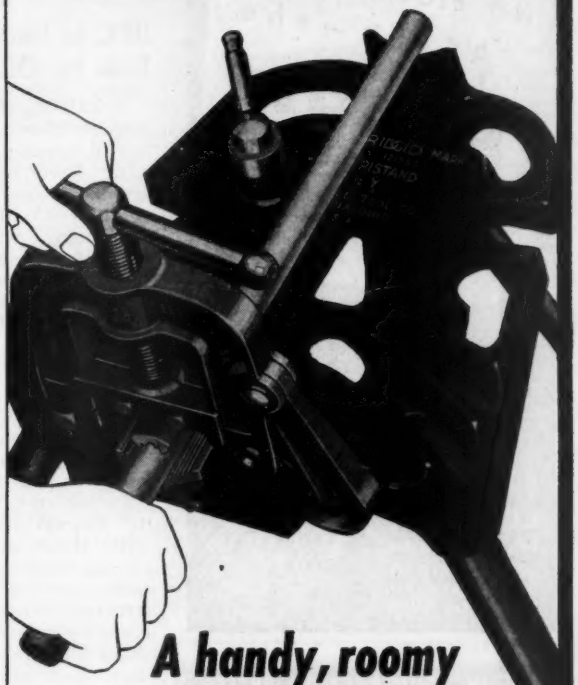
Specify **RODPAK**
METALLIC PACKING
for rods, shafts, inside & outside packed plungers

RODPAK MANUFACTURING CO.
1315 Natoma Street • San Francisco 3, California

REPRESENTATIVES

MACHINERY SUPPLIES COMPANY, 501 Madison Avenue, New York 22, N.Y.
RALPH E. MANNS CO., 1024 E. Anaheim Blvd., P. O. Box 277, Wilmington, Calif.
W. H. ROBER, 1016 1st Avenue, South, Seattle 4, Washington
STRIEBY & BARTON, Ltd., 912½ E. Third Street, Los Angeles 13, California

RIGID
Portable Tristand Vise



A handy, roomy workbench easily set up anywhere

• It isn't so much how handily the Tristand folds up, carries easily and sets up solidly exactly where you need it — it's the workbench convenience you like most. Look now — lots of room for dope pot and oil cans, slots to hang tools, a pipe rest and 3 very useful benders. And whether yoke or chain vise, you get tool-steel LonGrip jaws, easy on polished pipe. For easier work, convenience you'll enjoy — buy it at your Supply House.

RIGID
WORK-SAVER PIPE TOOLS
THE RIDGE TOOL COMPANY • ELYRIA, OHIO, U. S. A.

New POWER—
SPEED—STAMINA
to clean tubes
FASTER—the
ELLIOTT
1100 SERIES
TUBE CLEANER
Y-253
ELLIOTT
COMPANY
Lagonda Division
SPRINGFIELD, O.
DISTRICT OFFICES IN
PRINCIPAL CITIES

LEADING CONTRACTORS PREFER
Sterling
PUMPS • HOISTS • LIGHT PLANTS
DEPENDABLE
RUGGED
SIMPLE
•
SAVE
MONEY
SAVE
TIME
EASY
TO
OPERATE
•
WRITE
FOR
CATALOG
STERLING
QUALITY
STERLING
MACHINERY CORPORATION
405-13 SOUTHWEST BLVD. KANSAS CITY 10, MO.

REFINING

RFC to Receive Sealed Bids for Oil Equipment

WASHINGTON. — Reconstruction Finance Corp. has announced that it will receive bids up to 10 o'clock a. m., November 30, on unused government-owned surplus oil-refining equipment and used oil-drilling equipment, with spare parts, at RFC's Los Angeles office, in whose area the property is located. The property can be inspected by arrangement with the Los Angeles office.

Included in the refining equipment, all new, are a distillation unit of 4,600-bbl. daily capacity, of paraffin-type crude; crude fuel-flash unit, 11,000-bbl. daily capacity of heavy asphalt-type crude; naphtha-reformer unit, 1,600-bbl. daily capacity. Unused utilities offered for use with these units include transfer piping, blending and leading equipment; two control laboratories; construction tools, including welding equipment; machine shop and pipe shop, with power plant and buildings; and an oil-field warehouse stock. In addition, there are 34 unused welded steel tanks, with capacities ranging from 1,500 bbl. to 10,000 bbl.

Drilling equipment includes one used National Ideal 125 special drilling rig with spare parts complete, less derrick, and spare parts and replacements for six National Ideal No. 50 drilling rigs.

Interested persons may obtain general information from any RFC disposing agency office or detailed lists of this surplus equipment from the Los Angeles RFC office, Pacific Mutual Building, Los Angeles 14, Calif.

A.P.I. Provides Program On Personnel Training

CHICAGO.—A program on "Application of Visual Aids to Personnel Training," prepared by the American Petroleum Institute's committee on vocational training in refining, was presented November 12 in connection with the Institute's annual convention at the Stevens Hotel. Sterling Mudge, supervisor of training for Socony-Vacuum Oil Co., Inc., presided. Army and Navy officers described wartime use of training aids by the armed forces.

Speakers and their topics: William R. Stow, head of the training aids section, Division of Shore Establishments and Civilian Personnel, Navy Department, "Visual Aids in Civilian Personnel Training"; Col. W. E. Allen, Jr., military training division, Army Service Forces, "Application of Visual Aids to Military Training Programs"; Lt. Comdr. H. V. Hoagland, film-utilization officer, Petroleum Administration for War, "Armed Forces Film-Utilization Program."

A general discussion was led by Chairman Mudge. The addresses by Stow and Colonel Allen were supplemented by exhibits of audio-visual aids developed to meet specific training problems.

Magnolia's Toluene Plant To Be Sold or Leased

WASHINGTON.—Among 18 government-owned industrial plants being offered for sale or lease by

Steel Plate
Fabricators and
Contractors
•
Products storage
•
Pressure vessels
McNAMAR
BOILER & TANK CO.
Tulsa, Okla

GUNITE METHOD
SAND AND CEMENT
"Placed by Air"
WRITE — PHONE — WIRE
FOR SERVICE — INFORMATION
GUNITE CONCRETE
& CONSTRUCTION COMPANY
1301 Woodswether Road, Kansas City 6, Mo.
Distr. Br. Office: 228 N. LA SALLE, CHICAGO • *Branch Offices:* ST. LOUIS, DENVER, NEW ORLEANS, DALLAS, HOUSTON
"GUNITE" CONCRETE SINCE 1915

Reconstruction Finance Corp. is the toluene plant operated by Magnolia Petroleum Co. at Beaumont, Tex. All the plants, acquired by the Government for production in the war effort, are or soon will be declared surplus to government needs.

Bombed German Refinery Restored to Production

WASHINGTON.—Word has been received here to the effect that the large refinery at Misberg, one of the few German plants bombed in 1940, has been restored to production by two Allied officers, Capt. Roy Owens, of New York, and Maj. John P. Ashton, of Manchester, England.

When these officers arrived at Misberg, just outside Hannover, on April 13, they found little but twisted metal, cracked walls, smashed railway trucks and broken rails. The refinery had gone through one of the last bomber raids on March 15.

Although the consensus was it would take 6 months to recondition the plant, the Ashton-Owens team had it working at half the normal capacity in 3 weeks.

Misberg now turns out eight different grades of gasoline and diesel oil for German civilians in the British-occupied zone.

FTC's Order Cockeyed and Confusing, Says Majewski

CHICAGO.—The Federal Trade Commission's order in the case of Standard Oil Co. (Indiana) at Detroit is "astounding, cockeyed, confusing," in the opinion of B. L. Majewski, vice president of Deep Rock Oil Corp. The commission ruled that sales to jobbers at lower prices than to retailers are a violation of the Robinson-Patman Act if the jobbers operate retail outlets also. This apparently will compel suppliers to charge higher prices, with correspondingly higher prices to consumers resulting.

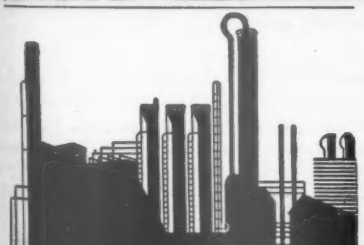
In a letter to Hugh L. Thatcher, chairman of National Council of Independent Petroleum Associations, Majewski says:

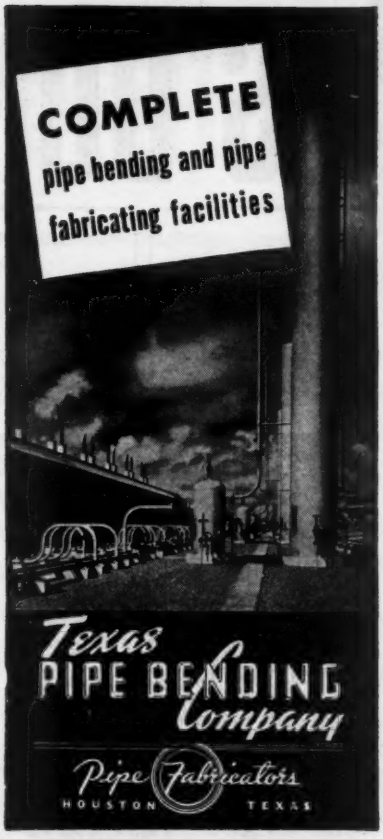
"While Standard Oil Co., as the supplying company, was the ostensible defendant, the people who really got the ax were Standard's Detroit jobbers and, to the same extent, everyone else who functions as a jobber in the oil business.

"Don't misunderstand me when I say the conclusions of the commission are astounding, cockeyed, confusing. I make no insinuation that the conclusions were not arrived at in good faith. Perhaps the Robinson-Patman Act itself is cockeyed. All I am saying is this: If the act requires the results announced by the commission in this Detroit case, then the jobbers and wholesalers of this country have had one slipped over on them of atomic proportions. If the act means what the commission says it means, then the jobbers of this country have been sold down the river. If they had been sold down the river to help someone else, they might unselfishly and patriotically suffer in silence; but a decision of this character ruins everybody, including the consumer. It requires everybody to remain small. It places a premium on inefficiency. It is a threat to free enterprise and a positive choke on competition.

"The only person who might conceivably be helped by such a decision is someone who has just one service station, who never hopes to have two, and is even afraid to face active competition at the one he does run. There are very few men of this character in America."

LET ME SHOW YOU WHAT GOOD WATER CONDITIONING SERVICE REALLY IS!
Call JOHN FIELD-MAN ON YOUR NEXT WATER CONDITIONING JOB
LELAND HAMNER CO.
LELAND HAMNER CO.
P. O. Box 1065 · Capitol 9758 · Long Distance LD 2175
2211 PRESTON AVE. HOUSTON, TEXAS


We design and construct all types of modern refining units.
★ Serving the Industry Since 1915 ★
BORN ENGINEERING CO.
Tulsa, Oklahoma



Easy Clean
TRADE MARK

Attention —

Drilling Contractors

Oil Producers

Transporters

Avoid costly shutdowns and repairs to engines due to overheating often caused by dirty or partially plugged cooling systems, by simply adding **EASY CLEAN** SOLVENTS to your present cooling water.

Guaranteed NON-INJURIOUS to rubber or metals, and to REMOVE accumulated scale and rust, **EASY CLEAN** will restore efficiency of your engine cooling system — regardless of size.

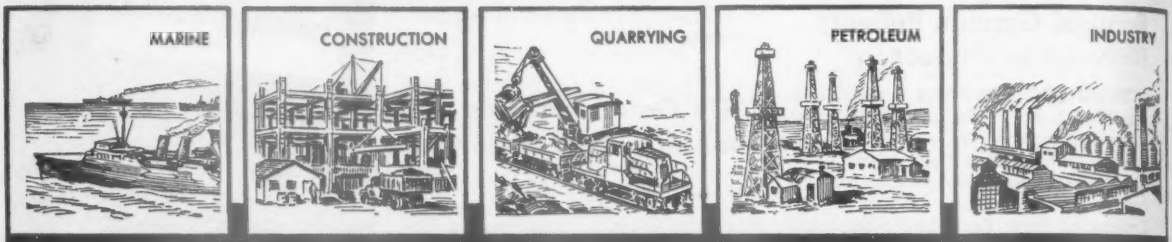
EASY CLEAN water treating service is backed by nearly 28 years of experience— Pumping Engines, Drilling Engines, Boilers, Cooling Towers, Spray Ponds, etc

Phone, wire or write for further information. Branch Office: 318 Thompson Bldg., Tulsa, Oklahoma. Phone 3-4564.

SOLVENT MFG. CO.
Manufacturing Chemists and Water Consultants
2130 SW 29th St. Oklahoma City
Phone 6-3405

XUM

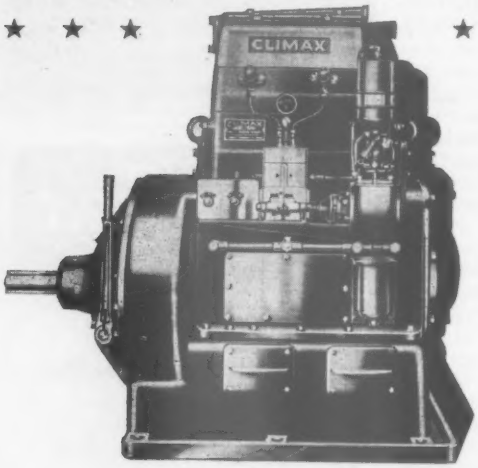
IT'S DONE WITH DIESELS



...CLIMAX Diesels!

Operating on CHEAP, LOW GRADE, Standard Fuel Oil

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★



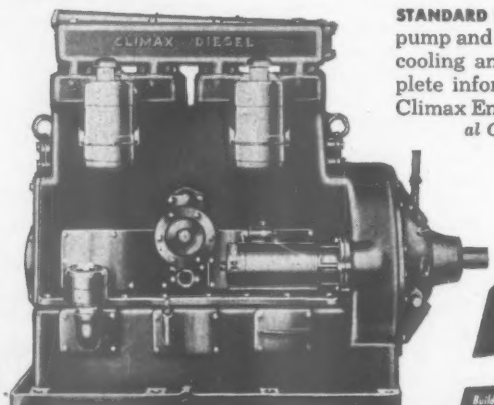
IN A SCORE OF INDUSTRIES—and in the marine, quarrying, petroleum and construction fields—these "little giants of Diesel power" are found driving fans and blowers, pumps, compressors, electric generators, conveyers and hoists, small locomotives, etc., powering boats and supplying auxiliary power on large vessels. Because—using less than ½ pint of low cost fuel per horsepower hour—these smooth-running Climax Diesels are incomparably *the most economical source* of dependable power available to small power users.

Built with one-piece construction of cylinder block and crankcase, they are strong and rugged, 4-stroke-cycle, solid injection, compression ignition engines that start at the touch of a button, by local or remote control.

CLIMAX MODEL D-148 Diesel Engine. Two cylinder, full Diesel with maximum rating of 22 h.p. at 1200 r.p.m. Also available with 15 kva generator.

★

CLIMAX MODEL D-297 Diesel Engine. Four cylinder, full Diesel, maximum rating 44 h.p. at 1200 r.p.m. Also available with speed reduction units, or with 30 kva generator.



STANDARD EQUIPMENT includes American Bosch fuel pump and injection nozzles, positive lubrication and cooling and electric starting equipment. For complete information and specification bulletins, write Climax Engineering Company, Clinton, Iowa. *Regional Offices: Chicago, Ft. Worth, Tulsa, Los Angeles.*

climax DIESEL
Builder of Climax BLUE STREAK ENGINES and GENERATING SETS

CLIMAX ENGINEERING COMPANY

MID-CONTINENT DISTRIBUTOR
The Continental Supply Co., General Offices, Dallas

CALIFORNIA DISTRIBUTOR
Climax Engines & Parts Co., 2050 Santa Fe, Los Angeles

Exploration and Drilling

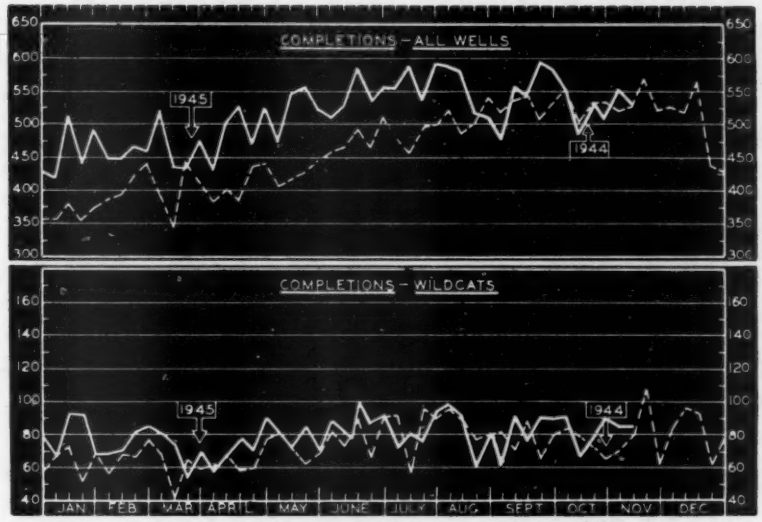
Week's Highlights

THE famous Hatchitigbee anticline of western Alabama is giving the geologists more food for thought. The recent discovery of a new field in Clarke County, Mississippi, by L. J. Russell et al 1 Long Bell Lumber Co., SE SW 10-2n-16e, is the cause of the revival of interest.

Russell's test is apparently a small well, pumping 37 bbl. of 13.7° gravity oil from the upper Eutaw, through perforations at 3,715-17 ft. It is in the Quitman area, which has been a center of interest and some sporadic drilling since 1931, when Gulf Refining Co. 1 Long Bell Lumber Co., SW SW 10-2n-16e, had the first show of oil ever found in Mississippi.

The area is on the northwest, or plunging nose of the Hatchitigbee anticline, well to the north of the structure axis. The new field is apparently similar to the Langsdale field of Mississippi and the Melvin and Gilbertown fields across the line in Alabama. All three are associated with a large fault that lies north of the axis of the main Hatchitigbee anticline. In all three the production is associated with closures against the fault. This fault can be traced on the surface for 20 miles or more, and has a trend only slightly off an east-west line.

The new field lies against a fault with a sharp northwest-southeast trend, some distance north of the projection of the fault associated with Langsdale, Melvin and Gilbertown. It may be the same fault,



Solid line charts current weekly completions—service wells included

WEEKLY WELL COMPLETIONS . . . WEEK ENDED NOVEMBER 10, 1945

	Total of all wells					Cum. to date		Wildcat completions and discoveries					Cumulative total, 1945				
	Comp.	Oil	Gas	Dry	Footage	1945	1944	Oil	Dist.	Gas	Dry	Total	Oil	Dist.	Gas	Dry	Total
New York	30	15	0	*15	43,350	1,269	1,391	0	0	0	0	0	0	0	0	0	0
Pennsylvania	75	40	3	†32	124,786	3,516	3,653	0	0	0	0	0	0	0	0	0	0
West Virginia	6	0	4	2	10,846	691	773	0	0	0	0	0	0	0	0	0	0
Ohio	24	6	10	8	54,082	846	873	0	0	1	0	1	0	0	14	53	67
Indiana	2	2	0	0	5,252	166	223	0	0	0	0	0	6	0	0	24	30
Kentucky	15	13	0	2	28,416	474	646	1	0	0	0	1	23	0	4	46	73
Illinois	53	28	0	15	131,376	1,565	1,653	3	0	0	10	13	47	0	0	275	322
Michigan	19	8	2	9	47,528	656	587	0	0	0	7	7	11	0	4	246	261
Kansas	30	15	6	9	93,918	1,494	1,586	2	0	0	6	8	33	0	12	295	340
Neb., Mo., Iowa	1	0	0	1	1,750	20	35	0	0	0	0	0	0	0	0	14	14
Oklahoma	66	42	5	19	243,124	2,061	1,562	1	0	0	8	9	76	3	15	305	399
Texas	124	57	19	48	569,489	6,157	4,837	4	0	0	22	26	181	14	50	1,089	1,334
North Central	37	11	1	25	101,910	1,875	1,259	1	0	0	11	12	69	0	5	382	456
West	27	17	0	10	98,727	1,509	1,379	0	0	0	2	2	46	1	0	219	266
Panhandle	6	1	5	0	18,303	470	246	0	0	0	0	0	0	0	1	6	7
Eastern	14	3	11	0	90,318	314	282	0	0	0	0	0	5	8	2	74	89
Gulf Coast	36	24	2	10	248,924	1,441	1,090	3	0	0	6	9	47	4	33	249	333
Southwest	4	1	0	3	11,307	548	588	0	0	0	3	3	14	1	9	159	183
Louisiana	28	19	0	9	170,558	921	697	2	0	0	3	5	31	3	6	108	148
Northern	14	9	0	5	55,936	385	281	0	0	0	1	1	8	1	6	61	76
Southern	14	10	0	4	114,622	536	416	2	0	0	2	4	23	2	0	47	72
Arkansas	4	2	0	2	19,460	154	188	1	0	0	1	2	2	0	0	33	35
Mississippi	7	4	0	3	51,275	317	124	1	0	0	3	4	6	0	0	105	111
Southeastern	1	0	0	1	4,457	51	44	0	0	0	1	1	1	0	1	35	37
Montana	2	1	1	0	5,179	272	310	1	0	0	0	1	10	0	0	24	34
Wyoming	4	4	0	0	15,759	191	150	0	0	0	0	0	17	0	1	42	60
Colorado	1	0	0	1	647	48	30	0	0	0	1	1	1	0	1	11	13
New Mexico	5	2	0	3	19,040	367	347	0	0	0	3	3	10	0	6	59	75
California	31	24	1	6	122,973	1,945	1,729	0	0	0	3	3	4	0	2	204	210
Total United States	528	282	51	185	1,763,265	23,181	21,438	16	0	1	68	85	459	20	116	2,968	3,563
Total previous week	555	279	52	224	2,018,733	22,653	20,894	13	1	1	69	84	443	20	115	2,900	3,478
Total Nov. 11, 1944	522	276	53	193	1,669,361	21,438	15,343	11	2	2	64	79	386	26	109	2,775	3,296

Service wells included: *15. †30.

taking a sharp change of direction, but is more likely a cross fault.

Whatever the local peculiarities may be, the point is that oil has now been found in four places along major faulting that is associated in some way with a large regional structure, the Hatchitigbee anticline. Therefore there is some oil accumulation in the area affected by this feature. Testing on top of the structure has been disappointing, but now further study is indicated, because chances of finding major accumulations of oil somewhere along or near such a regional trap look good.

LA.-ARK.

New Pettit Pool Likely For Caddo Parish

SHREVEPORT. — Union Producing Co. 1-A Noel estate, 11-19n-16w, a wildcat about 3 miles south of the Caddo field of Caddo Parish, recovered 120 ft. of oil, 50 ft. of basic sediment, and 10 ft. of salt water on a drill-stem test. Recovery was from the Pettit at 5,701-16 ft., and operators are drilling ahead at 5,755 ft. for the Travis Peak.

In Columbia County, Arkansas, Blaine Dunbar 1 Reed & Biddle, 660 ft. west and 270 ft. south of NE corner of 34-19s-20w, possible extension to the Haynesville field, is still trying to complete. Perforations were made and good shows reported but cement trouble is causing delay. Total depth is 5,716 ft.

Arkansas completions totaled four, including two wildcats. Brown & Wheeler 1 Carey Clark opened a new pool for Union County, and the other wildcat was a dry hole in White County.

In the North Louisiana fields, 14 completions were announced, including 9 oil wells and 5 dry holes, 1 of which was a wildcat. Caddo and Big Creek fields took the lead with three completions each.

NORTH LOUISIANA WILDCAT FAILURE

Natchitoches Parish: California 1 Lee, 664 ft. south and 1,958 ft. east of NW corner of 18-13n-7w, dry, TD 3,224 ft.

ARKANSAS SUCCESSFUL WILDCAT

Union County: New oil pool—Brown & Wheeler 1 Clark, SW SW 22-18s-12w, 60 bbl. day from Cotton Valley at 4,817-22 ft., TD 6,350 ft.

ARKANSAS WILDCAT FAILURE

White County: Lion 1 Nolley, SE NE 33-8n-7w, dry, TD 6,397 ft.

SOUTH LOUISIANA

New Sand Opened In University Field

NEW ORLEANS. — William Helis has opened new sand in University field, East Baton Rouge Parish. His 15 R. E. Nelson, 36-7s-1w, was drilled to a total depth of 9,991 ft., with perforations at 9,958-70 ft. Top of sand was at 9,955 ft. On potential test the well flowed 160 bbl. of 51°-gravity oil through a 12/64-in. choke, tubing pressure 1,700 lb.

Humble Oil & Refining Co. has completed 5 Sarpy Brothers in the Good Hope field of St. Charles Parish. The well gaged 346 bbl. of 36°-gravity oil in 24 hours through a 3/16-in. choke. Tubing pressure is 1,200 lb., and gas-oil ratio 688 to 1. Total depth is 7,838 ft. with 5½-in. casing set on the bottom. Perforations were 102 shots from 7,795-7,812 ft.

Humble 1-B J. A. Bel Estate, deep wildcat test in the Oberlin area of Allen Parish, 33-5s-4e, is drilling below 12,448 ft. in sand and thin shale streaks. A 30-ft. section of gas-bearing strata was cored from 12,200-230 ft. with the top 10 ft. being clean gas sand, and the bottom 20 ft. sandy shale showing gas. A show of oil was encountered from 12,106-115 ft.

There were 10 new locations reported this week, 2 being wildcats, 1 each in Cameron and St. Charles parishes. Of the 14 completions reported 10 are producers, with 2 new sand discoveries, and 2 dry wildcats, 1 each in Cameron and St. Landry parishes. One new sand is in University field in East Baton Rouge Parish, while the other is in Bayou Des Glaise field in Iberville Parish.

SOUTH LOUISIANA SUCCESSFUL WILDCATS

East Baton Rouge Parish: New sand University field—William Helis 15 R. E. Nelson, 36-7s-1w. TD 9,991 ft., perf. 9,958-70 ft., top sand 9,955, PT 160 bbl. per day through 12/64-in. choke, TP 1,700 lb., gravity 51°, no water.

Iberville Parish: New sand Bayou Des Glaise field—Humble Oil & Refining Co. 6-B Wilbert Mineral Corp., 76-8s-8e, TD 10,895 ft., perf. 10,434-444 ft., top sand 10,431 ft., PT 268 bbl. per day through a 9/64-in. choke, gas-oil ratio 682 to 1, TP 1,835 lb., gravity 36°, water 0.1 per cent.

SOUTH LOUISIANA WILDCAT FAILURES

Cameron Parish: Continental Oil Co. 3 State-Calcasieu Lake, in Lake Sec. 33-13s-9w, dry at 7,872 ft.

St. Landry Parish: Phillips Petroleum Co. 1 Nienstedt, 20-4s-6e, dry at 12,530 ft.

CALIFORNIA

New Locations Again Exceed Completions

LOS ANGELES.—There was no material change during the week in the status of Standard Oil Co. of California's Lewis wildcat between Santa Fe Springs and West Coyote fields or Ohio Oil Co.'s wildcat at Gardena. Ohio had its 1 Gardena flowing several months ago but subsequently took it off production when the water cut continued to increase. The company has been attempting to solve this water problem but with only fair results. Standard gave up the attempt to complete its Leffingwell wildcat on the Lewis property a few weeks ago and resumed drilling in the hope of finding a deeper sand. This wildcat looked quite promising but failed to show any kick on a formation test.

Richfield Oil Corp. is engaged in a redrilling job on its wildcat in Section 9-2s-12w, which was down 8,496 ft. when a fishing job developed. Redrilling work is now going forward at 7,700 ft. Richfield has started a second wildcat at Bandini on the Simons property in Section 15-2s-12w, which is drilling ahead at 4,780 ft. Chanslor Canfield Midway Oil Co. started a wildcat in Section 21-2s-12w, due south of Richfield's original wildcat. C. G. Willis is drilling a wildcat on the Pansini property in Section 23-2s-12w, and recently landed 7-in. casing at 8,195 ft. As a result of this work there is now a line of wildcats extending from northwest to southeast and a fourth wildcat south of Richfield's U.P. Unit.

The development work involving schist production in the Edison field of Kern County is rapidly getting under way. H. H. Magee proved the schist basement productive a few months ago but it took operators some time to determine whether to engage in aggressive drilling or take it by easy stages. Subsequently some large flowing wells were completed and now every operator holding acreage within the limited area has either already started drilling or deepening operations or has plans to do so at once. Production is developed from a fractured schist basement and it is the present custom to drill about 120 ft. into the fractured schist until the solid schist basement is

DAILY AVERAGE PRODUCTION FOR WEEK

	Nov. 10 crude oil	Bureau of Mines demand forecast	State allowable	Nov. 3 crude oil
Alabama	550	100	.....	150
Arkansas	76,100	78,000	.....	75,050
California	835,250	860,000	880,000	839,750
Colorado	15,400	12,000	.....	14,850
Eastern	66,300	65,200	.....	62,850
Florida	100	200	.....	150
Illinois	206,300	215,000	.....	204,600
Indiana	13,800	13,500	.....	13,800
Kansas	243,800	270,000	255,000	241,850
Kentucky	28,450	28,000	.....	29,400
Louisiana	367,800	365,000	398,733	362,150
North Louisiana	74,150	.....	.....	73,450
South Louisiana	293,650	.....	.....	288,700
Michigan	47,200	47,000	.....	46,100
Mississippi	53,500	48,000	.....	53,850
Montana	22,700	23,200	.....	22,650
Nebraska	750	800	.....	800
New Mexico	101,550	102,000	104,000	102,000
Oklahoma	390,150	390,000	390,000	362,800
Texas	1,894,200	1,990,000	2,016,198	1,790,000
East Texas	316,500	.....	.....	308,000
East Central Texas	128,000	.....	.....	122,200
North Central Texas	147,100	.....	.....	139,800
Texas Panhandle	81,000	.....	.....	85,000
West Texas	457,750	.....	.....	422,450
Southwest Texas	300,100	.....	.....	282,800
Texas Gulf Coast	464,250	.....	.....	429,750
Wyoming	95,250	92,000	.....	91,150
Total United States	4,459,150	4,600,000		4,313,950
Change from prev. week, up	145,200			

Total production January 1-November 10, 1945 ..... 1,475,978,925 bbl.
Same period last year ..... 1,432,241,950 bbl.

Cleaning Pumping Station Floors!

DO NOT permit pumping station, barrel house and dock floors to accumulate oil and grease deposits. When you do, the danger of ACCIDENTS due to slipping and constant FIRE hazard are ever-present.

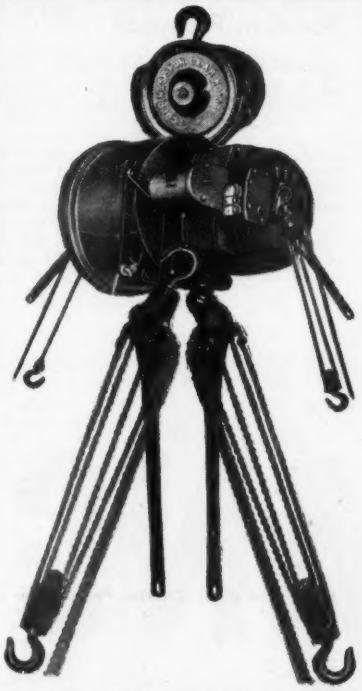
You can overcome this serious condition easily by using one of the Oakite materials specially designed for floor cleaning. The extraordinary emulsifying and detergent action of these materials quickly loosens tenacious deposits so that a light brushing or pressure rinse easily carries them away. Free-rinsing, Oakite materials leave floors clean, FILM-FREE, safe.

Free Help for You!

You can secure the FREE, competent help of one of Oakite's Field Service Engineers on this or any of your other maintenance cleaning problems by sending request to the address below. Do it TODAY!

OAKITE PRODUCTS, INC.
44C Thames Street, New York 6, N.Y.
Technical Service Representatives Located in All Principal Cities of the United States and Canada

AVAILABLE SOON



COFFING
LIFTING and PULLING EQUIPMENT

Will soon again be available for your production, construction and maintenance jobs. After almost four years of day and night production for the Armed Forces we are now in position to accept and schedule your orders. We are proud of the production record we have made and of the important part COFFING products played in helping to restore Peace on Earth. Our standard line of hoists were used by our fighting men so there is no reconversion period for us.

Write for Folder No. 4

COFFING HOIST COMPANY
Danville U.S.A. Illinois

Come Your
VIKING PUMPS

The Viking factory, which has been devoted 90% to producing pumps for the armed forces, is being reconverted to civilian production as rapidly as possible.

You should note a gradual but substantial increase in Viking pumps available for your industry by November 1st. This picture should be considerably brighter by January 1st, 1946.

Write today for Bulletin Series 3000T which describes and illustrates Viking Rotary Pumps widely used in the petroleum industry. It will be sent FREE by return mail.

VIKING PUMPS — FIRST IN AMERICA

VIKING Pump COMPANY
CEDAR FALLS IOWA

reached. Initials have ranged from 250 to 2,000 bbl. per day. Some old wells are being deepened and some new holes have been started.

For the second time in several weeks, new locations have exceeded completions.

CALIFORNIA WILDCAT FAILURES

Kern County, Antelope Hills: The Mitchel Co. 1 Mitchel fee, 12-28s-19e, bottomed in hard shale, no showings, TD 850 ft.

Round Mountain: Independent Exploration Co. 3 Heisen, 36-27s-28e, bottomed in barren gray sand, Vedder sand of Miocene age at 852 ft. was barren, TD 858 ft.

Sacramento County, Sacramento: Jergins Oil Co. 1 Sacramento, 23-8n-4e, bottomed in hard gray sand, no showings of importance, TD 7,460 ft.

MICHIGAN

Deep River Development Boom in Prospect

SAGINAW.—A new development boom is in prospect for Arenac County's Deep River Township oil field, location for 9 of the 24 drilling starts announced in the past week. Completions totaled 19, including 3 heavy oil producers in the Deep River field, another good well in Isabella's Coldwater field, 4 small producers, 2 gas wells and 9 dry holes. Seven of the dry holes were wildcat tests. The four good wells provided all but 200 bbl. of nearly 12,000 bbl. in new daily potential, the Deep River wells coming in at 250, 135, and 51 bbl. an hour, while the Deep River completion flowed 206 bbl. the first five hours and increased prospects for lower strata production. Completion depth in that well, Sohio Petroleum Co. 2 Hoffman, was 5,090 ft.

Other new locations are: four in Van Buren County, three in Bay, two each in Allegan and Mecosta, one each in Clare, Kent, Lake and Osceola counties.

MICHIGAN WILDCAT FAILURES

Arenac County, Arenac Township: Sun 1 Tulloch, SW SW SE 17-19n-5e, dry in Dundee, TD 3,049 ft.

Deep River Township: Michigan Oil 1 Herzberg, SW SW SW 7-19n-4e, dry in Dundee, TD 3,102 ft.

Genesee County, Montrose Township: Michigan Oil 1 Woodward, SE SE SE 10-9n-5e, dry, TD 1,751 ft.

Gladwin County, Butman Township: T. F. Caldwell, Inc., 1 Lentner Bros., SE SE SW 32-20n-1w, dry in Dundee, TD 3,763 ft.

Muskegon County, Blue Lake Township: Michigan Oil 1 Haywood, NE NW NW 36-12n-16w, dry in Traverse limestone, TD 1,967 ft.

Oceana County, Crystal Township: Charles W. Teater 1 Ryan, S½ NW NW 16-16n-16w, dry in Dundee, TD 2,719 ft.

Hillsdale County, Litchfield Township: Clifford A. Perry 1 Wright, SE NW NW 9-5s-4w, dry, TD 1,629 ft.

TEXAS GULF COAST

Altair Field Extended By Superior Well

HOUSTON.—The Altair field of Colorado County has been extended to the west by Superior Oil Co. 1 Pryor, which is west of its 2-A Matilda Tait, discovery well of the field. The 1 Pryor, testing in perforations 8,242-50 ft., flowed at the rate of 349 bbl. per day through a ¼-in. choke (based on a 12-hour gage), tubing pressure 1,530 lb., gravity 56°. Gas-oil ratio 3,444 to 1. Total depth is 8,399 ft., with 7-in. casing set to bottom.

Frio production has been opened by H. W. Snowden in the Lane City field of Wharton County. The 2 H. C. Cockburn flowed a potential of 85 bbl. of pipe-line oil daily through a 3/16-in. choke, through perforations at 5,433-37 ft. Tubing pressure 165 lb., casing pressure 520 lb. Gas-oil ratio 270 to 1. Total depth is 5,452 ft., with top of sand at 5,430 ft. This is the first well producing from the Frio in the field.

Humble Oil & Refining Co. 1 E. C. Hankamer et al, discovery well for the South Call area of Newton County, located in the J. B. Smith Survey, Abstract 790, on production test is flowing 80 bbl. of 62° gravity condensate, 11/64-in choke, with 2,575 lb. pressure on the tubing. Previously the well flowed 38 bbl. of 62° gravity condensate through a ½-in. choke, from 36 perforations at 7,960-66 ft. A fishing job developed after squeezing these perforations.

Pan American Production Co. 1 Olive Sternenberg Lumber Co., a wildcat test, in the P. S. Watts Survey, Abstract 571, Hardin County, assured a new field for the county, when it flowed 150 bbl. of 44°-gravity oil daily on test, using a 3/16-in. choke. Working pressure was 2,500 lb. with estimated gas-oil ratio 12,000 to 1. Operators are pulling tool and will probably core ahead for further tests before completion.

There were 20 new locations reported this week, 6 being wildcats, 1 each in Brazoria, Jefferson, Liberty, Matagorda, San Jacinto, and Wharton counties. Of the 22 completions, 5 were wildcats, 2 new sands, 1 each in Nash Dome, Fort Bend County, and Lane City field, Wharton County.

FOR THE BEST IN CABLE TOOLS

SPANG
FULL CIRCLE SLIP SOCKETS
(Fig. F482)
and
COMBINATION SOCKETS
(Fig. F497)

Fig. F482 Fig. F497

Spang Slip and Combination Sockets are rugged and tough. Room in the hole to add mass is limited, so Spang has substituted steel quality and heat treatment to give that extra strength needed to stand long heavy jarring when it is necessary.

They are carefully forged, thoroughly heat treated, and accurately machined. You can count on them!

Even a soft, simple fishing job can get tough and complicated. That's why it pays to always use only the best fishing tools for any fishing job. For the best in Cable Tools, SPECIFY SPANG.

THE HIGHER STANDARD

SPANG & CO.
BUTLER, PA.

YOUR DEALER SELLS SPANG TOOLS

and 3 dry holes, 1 each in Chambers, Harris, and Lavaca counties.

UPPER GULF COAST TEXAS SUCCESSFUL WILDCATS

Fort Bend County: Nash Dome new sand—Danciger Oil & Refining Co. 1 Theodor Meier, H. N. Cleveland Sur., TD original hole 6,503 ft., plugged back and sidetracked, drilled to 5,893 ft. in sidetracked hole. Perf. 5,860-75 ft., PT 240 bbl. per day through a 12/64-in. choke, 1,300,000 cu. ft. gas, gas-cut oil ratio 5,000 to 1, TP 2,000 lb., casing pressure 2,300 lb., gravity 30°, no water.

Wharton County: New sand Lane City field—H. W. Snowden 2 H. C. Cockburn, S. Castleman Sur., Blk. 105, top Frio sand 5,430 ft., TD 5,452 ft., perf. 5,433-37 ft., PT 85 bbl. per day through a 3/16-in. choke, gas-oil ratio 270 to 1, TP 165 lb., CP 520 lb., gravity 24°, no water.

UPPER GULF COAST WILDCAT FAILURES

Chambers County: E. R. Brann 1 Geo. F. Wilborn, T&NO Sur., Abst. 257, Sec. 7, 13 miles south of Anahuac, dry at 10,010 ft.

Harris County: J. C. Wynne and W. E. Allaun 1 S. & H. Oil & Royalty Co., J. H. Isbell Sur., Abst. 475, 4 miles NW Huffman, dry at 8,510 ft.

Lavaca County: G. W. Strake and Tide Water Associated Oil Co. 1 L. C. Wolfsdorff, Sublime area, Miguel Muldoon Sur., dry at 9,010 ft.

SOUTHWEST TEXAS

Humble Opens Production In Dimmit County

CORPUS CHRISTI.—Humble Oil & Refining Co. is opening new production in Dimmit County at 1 Davis which was cleaning from 42 perforations at 2,710-17 ft. Total depth is 7,550 ft. with 5½-in. casing set to 2,767 ft. A squeeze job had been made at 2,725-27 ft. before perforating for this test. Reports show this to be a large gas well.

Pettus sand production in the Burnell-Wilcox field of Bee County has been opened by Blanco-Buchanan 1 C. A. Henderson et al. Drilled to a total depth of 3,518 ft., this well flowed 35 bbl. daily through a ¼-in choke through 15 perforations at 3,515-17 ft. Tubing pressure was 200 lb., very little gas. There was no water in the flow.

Humble 1 Henry Schorsch, wildcat in Edward Esteda Survey, Atascosa Colony Farms Subdivision, Block 24, ¾ miles southwest of Jourdanton, in Atascosa County, is coring ahead from 7,316 ft. in Edwards lime. A drill-stem test at 7,277-88 ft. had recovered some condensate while tests at 7,285-93 ft. and 7,292-7,300 ft. had recovered gas-cut mud.

The name Pita has been given the field discovered by Humble 1-B Sullivan, in San Antonio de Encinal Survey, Brooks County.

Final completion is under way at Quintana Petroleum Corp. 1 Shofner, Rodriguez Survey, wildcat discovery well in the Port Lavaca area of Calhoun County. It is reported the well is being completed in the 5,710-20-ft. sand where oil was recovered in a 25-minute drill-stem test. The well now is flowing into tanks without a gage, with tubing pressure around 900 lb. Total depth is approximately 5,900 ft.

There were 39 locations reported this week, 10 being wildcats, 2 each in Live Oak and Webb counties, and 1 each in Bee, Brooks, Guadalupe, Nueces, Victoria and Willacy counties. Of the 26 completions, 7 were wildcats, with 1 new sand in La Sal Vieja field, Willacy County, 6 dry holes, 1 each in Brooks, McMullen, San Patricio, Victoria, Williamson and Webb counties.

SOUTHWEST TEXAS WILDCAT FAILURES

Brooks County: Sun Oil Co. 4-A Mary M. Lasater, HE&WT Sur. 349, 6 miles SE Falfurrias, dry at 5,548 ft.

McMullen County: John F. Camp 2 J. W. Atkinson, AB&M Sur., Sec. 125, 7 miles N Seven Sisters, 2 miles NE Loma Alta field, dry at 2,100 ft.

San Patricio County: Tom Graham 1 R. Morgan, Stockton Sur., Abst. 241, 7 miles W of Sinton, dry at 6,529 ft.

Victoria County: Monday Oil Co. 1 C. E. Stubblefield, Polito Castillo Sur., 9½ miles SE of Victoria, dry at 6,840 ft.

Williamson County: H. C. Lefors 1 John Filla, F. N. Stille Sur. 7 and 8, 2 miles N of Thrall, dry at 888 ft.

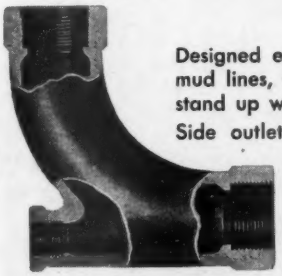
Webb County: John F. Camp 1 Marrs McLean, Henry Jones Subd. of E. Garcia Tract, Blk. 7, 9 miles SE of Mirando City, dry at 2,308 ft.

SOUTHWEST TEXAS SUCCESSFUL WILDCAT

Willacy County: New sand La Sel Vieja field—Magnolia Petroleum Co. and J. S. Abercrombie Co. 1 Harvey Geis, San Juan De Carricitos Grant, 3 miles west of Raymondville, top sand 8,935 ft., TD 10,098 ft., perf. 8,935-55 ft., PT 86 bbl. per day through an 18/64-in. choke, gas-oil ratio 50,000 to 1, TP 2,600 lb., gravity 54°.

THESE TWO QUALITY PRODUCTS

Originally introduced by "Brauer" are now made by us to the same high standards of materials and workmanship which have gained for them wide acceptance by operators everywhere. New plant machinery and added workmen assure delivery on receipt of order for either domestic or export service.



LONG SWEEP ELL

Designed especially for making turns in high pressure mud lines, this fitting reduces frictional losses and will stand up where ordinary connections cut out.

Side outlets provided for extra connections such as release lines, mud-mixing, etc. Ells made and tested to withstand working pressures of 3000 pounds.

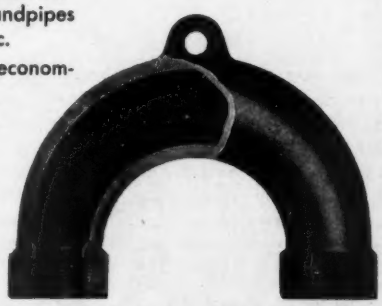
Sizes: 3" with 2" or 3" side outlet, 4" with 2" or 4" side outlets, 3" to 4".

STANDPIPE GOOSENECK

A superior fitting used extensively for making the return bend on top of standpipes instead of common tees, nipples, etc.

Proven in the field to be the most economical arrangement when long service and safety are desired. Tested for 3000 pounds working pressure.

Sizes: 3", 4" and 3" to 4".



BIG FOUR 4 AND MACHINE SUPPLY COMPANY

MANUFACTURERS OF BRAUER PRODUCTS

Brauer Portable Drilling Rig . . . Brauer Standpipe Gooseneck . . . Brauer Drill Pipe Floats . . . Brauer Long Sweep Ell . . . Brauer Improved Release Valve . . . Brauer Hydraulic Wall Hook . . . Brauer "Slim Hole" Swivel.

BIG FOUR MACHINE AND SUPPLY COMPANY

CLAY CITY, ILLINOIS

OHIO, KENTUCKY

Hopewell Gas Pool Extended 1 Mile South

COLUMBUS.—In the Somerset area, W. J. Sloan et al 1 Jess Underwood, Section 32, Hopewell Township, Perry County, extends the old Hopewell gas pool 1 mile to the south. Clinton sand at 2,945-77 ft. gaged 640,000 cu. ft. In the same township, Industrial Gas 5 G. M. Vlerebomi, Section 3, made 75 bbl. in 24 hours. Clinton sand was found at 2,943-75 ft.

A half-mile extension to the Bedford pool was found by Nollem Oil & Gas 1 E. R. Heaton, Section 1, Bedford Township, Meigs County. Berea sand at 1,672-91 ft. swabbed 40 bbl. the first day.

Indications of another small gas pool was found along the west side of Eaton Township, Lorain County. Ohio Fuel Gas Co. 1 H. J. Wilson, Lot 84, gaged 1,690,000 cu. ft. from Clinton sand at 2,444-59 ft. An offset location to the east will further test the area.

Twenty-nine locations were reported for the week with 11 in the Cambridge field. Five of these were in the town of Stafford, after Injun sand oil. Ashland field led in completions with 8 out of 24.

OHIO SUCCESSFUL WILDCATS

Medina County, Homer Township: P. Ringler et al 1 H. L. Low, Sec. 8, Clinton 2,826-36 ft., 175,000 cu. ft., TD 2,843 ft.

EASTERN KENTUCKY

ASHLAND.—Completion of one well and one dry hole note marked eastern Kentucky operations during the week.

Bed Rock Gas & Petroleum Co. completed No. 26 on the E. R. Caudill property, on Caudill Fork of Burton Fork, at a total depth of 2,440 ft., as dry.

WESTERN KENTUCKY

OWENSBORO.—Thirteen wells, all producers, were completed in western Kentucky in the past week. The wells ranged from 624 bbl. down to 7 bbl. in initial production, but averaged 100 bbl. per well.

Carter Oil Co. 2 Cordia Markham, in the North Waverly pool, Union County, started at 624 bbl. from Cypress sand at 2,328-33 ft. Ashland Oil & Refining Co. 3 fee in the same pool, produced 200 bbl. initially from Cypress sand at 2,266-93 ft.

One wildcat 2 miles south of Sturgis, Union County, got a 7-bbl. initial production in Hardensburg sand at 1,352-59 ft.

WESTERN KENTUCKY SUCCESSFUL WILDCAT

Union County: Farmer & Chenault 3 Slaton, 24-M-19, 2 mi. S of Sturgis, Hardensburg sand 1,352-59 ft., IP 7 bbl. Sturgis pool extension.

INDIANA

EVANSVILLE.—Only two wells were reported in Indiana during the past week, both producing wells in Gibson County.

Magnolia Petroleum Co. 1 E. L. Dike, SW SW SW 25-2s-13w, testing Aux Vases pay at 2,654-61 ft., which had been acidized, produced 35 bbl. of oil in 6 hours.

Because they have built into them the vital, extra capacity for smooth, dependable, trouble-free operation under the severest stresses and strains to be encountered in the world's most powerful machinery, AMERICAN SUPER HEAVY-DUTY ROLLER BEARINGS have been first choice for over 25 years with most manufacturers of heavy industrial and oil country equipment. Brutally strong, simply constructed, precise—AMERICANS give continuous, 24-hour-a-day service for maximum periods with minimum maintenance, often outlasting the equipment itself. Once adopted, no manufacturer has ever had to switch from AMERICANS.

Write for specifications or send us your requirements for analysis and recommendations. Our engineering experience is at your service without obligation.

AMERICAN ROLLING BEARING CO., Pittsburgh, Pa.

Pacific Coast Office: **1718 S. Flower St., Los Angeles, Calif.**

AMERICAN ROLLER BEARINGS HEAVY DUTY

AMERICAN
Heavy-Duty ROLLER BEARINGS

APPALACHIAN FIELD

Good Gas Well Completed In Oceana District

PITTSBURGH.—In West Virginia, United Producing Co. completed a good gas well in Oceana district, Wyoming County, with 1,191 Pardee Land Co., gaging 3,816,000 cu. ft. gas after shot. The Maxton sand was placed at 1,912-59 ft., shot at 1,938-56 ft., rock pressure 705 lb. in 92 hours. The gage before shot was 1,356,000 cu. ft. In Wyoming County, where large reserves are being drilled, there are 28 operations under way at the present time. In neighboring Raleigh County, four are under way and to the northwest in Logan County seven are drilling.

New locations totaled 14 and were situated in Crook district, Boone County; Sheridan district, Calhoun County; Center district, Gilmer County; Union district, Kanawha County; Skin Creek district, Lewis County; Graham district, Mason County; Jefferson district, Pleasants County; Scott district, Putnam County; Union district, Ritchie County; Lincoln district, Tyler County; Butler district, Wayne County, and Union district, Wood County.

In southwest Pennsylvania, Apollo Gas Co. completed a good well in a test on George Householder farm in Bethel Township with a gage of 920,000 cu. ft. gas with Murraysville sand topped at 1,266 ft., gas 1,274 ft., total depth 1,281 ft.

In Mercer County, Beal & McCandless continued drilling the deep test on J. Paul Miller farm in Lake Township and reached 5,586 ft. after shooting the formation at 5,460-88 ft. The Niagara was at 4,960 ft. and resultant gage 75,000 cu. ft. It is 4 miles removed from other deep sand production.

A wildcat that may extend the New Harmony pool ½ mile west, but not yet a completion, was Lynch, Heath et al 1 Joe Vail, near C N½ SW SW 14-5s-14w, Posey County. Waltersburg sand at 2,106-52 ft. and Degonia sand at 1,856-68 ft. both show saturation.

No wildcat wells were completed during the week.

CHECK IT BY ANY TEST - -

OUR invitation to subject the Davey Compressor to the acid test of comparison is backed by the fact that it will deliver its rated output over a longer period of time than any other compressor, that its long-run cost is less.

Davey guaranteed-for-life valves provide just one of the many reasons for this superiority of Davey Compressors. Davey conservative-speed operation is another big factor adding to its long, trouble-free service. Add other Davey engineering features such as welded steel frame, aluminum alloy cylinder heads and automotive type steering and you can see why we invite product comparison.

Write For Catalog E-172 for full information on the complete line of Davey Compressors, Heavy-Duty Truck Power Take-Offs and Pneumatic Saws.

D-545-20

DAVEY *Compressor Co.*
KENT · OHIO

DEALERS IN PRINCIPAL CITIES

STANDARD OF THE OIL FIELDS

Gotkool

WATER CANS & COOLERS

GOTKOOL WATER CAN
Made in 1½, 2, 3, 5, 10, 15 and 20 gallon sizes. (Push Button Faucet at slight additional cost.)

GOTT Water Cans are the practical way to keep drinking water cool for long periods, protected from impurities and always handy to the job. Snug fitting large removable top, strongly built to withstand rough usage. Gott Water Coolers have extra large covers and a handy non-leaking push button faucet. Your Supply Store has them, get one today.

GOTKOOL WATER COOLER
Made in 2, 3, 5, 8, 10, 15 and 20 gallon sizes with Push Button Faucet

H. P. GOTT MFG. CO.
WINFIELD, KANSAS

KEEP PURE DRINKING WATER ALWAYS HANDY

INSIST ON THE GENUINE
Look for the Blue and Black Label with the name GOTKOOL in Red

Dependability

Martin Black Wire Ropes

MARTIN, BLACK & CO., (WIRE ROPES) LTD., SPEEDWELL WORKS, COATBRIDGE, SCOTLAND.

Send for a copy of our leaflet, "Give Your Ropes a Chance" which illustrates the right and wrong method of handling Wire Ropes

Agent in Argentine: F. Lawson Kerr, Casilla de Correo 1391, Buenos Aires.

XUM

PERMIAN BASIN

Humble Well Midland County's First Producer

MIDLAND.—Humble Oil & Refining Co. 1 Mrs. O. P. Buchanan, Section 32, William Baldridge Survey, 9 miles southeast of Midland, is Midland County's first oil producer. It flowed 270 bbl. of 45.7° oil plus 32 bbl. of water on a 24-hour official gage. Gas volume averaged 1,172,000 cu. ft. daily and gas-oil ratio was 4,350 to 1. The flow was through an 11/32-in. choke. Tubing pressure ranged from 2,050 to 350 lb. and casing pressure from 2,950 to 1,700 lb. Production is from the Strawn lime of the Pennsylvanian through perforations from 10,370-90 ft. Humble has staked a half-mile outpost to the discovery. It is 2 Buchanan, 660 ft. from the south and west lines of Section 32, William Baldridge Survey.

Ector County.—Two wells being drilled on the east side of the TXL district show possibilities of production in the Simpson zone. The Texas Co. 1 Thomas, Section 8, Block 45, T-1-S, T&P Survey, a half-mile east outpost to Ellenburger production in the pool, on a 150-minute drill-stem test of the McKee section of the Simpson from 8,993-9,067 ft. recovered 600 ft. of drilling mud heavily cut with oil. It was drilling below 9,308 ft. in lime. The other test is Phillips Petroleum Co. 2-A TXL, Section 21, Block 45, T-1-S, T&P Survey, ¼ mile east outpost to Ellenburger production in the field, ran a 2-hour drill-stem test from 8,959-9,146 ft., also in the McKee section of the Simpson. There was gas to the surface in 30 minutes, averaging 149,000 cu. ft. daily. Recovery was 500 ft. of drilling mud and 3,000 ft. of 42.8°-gravity oil. It is drilling below 9,337 ft. headed for the Ellenburger. Texas 29 Connell, Section 9, Block B-16, Public School Lands Survey, 1¼ miles north of the Penwell field was drilling below 8,180 ft. in shale and lime.

Humble 1 Parker, Section 24, Block A-41, Public School Lands Survey, opens a new and deeper pay for the Martin pool of southern Andrews County. The well flowed 380 bbl. of 41.7°-gravity oil in 19 hours through perforations from 8,700-50 ft. This is in the McKee section of the Simpson. On a former drill-stem test from 8,775-90 ft. of the lower part of the McKee section it failed to develop oil or gas. It was drilled to 9,072 ft. where it failed in the Ellenburger. It was waiting on an official gage. DeKalb Agricultural Association will seek extension to the Drinkard pool of Lea County in Andrews County only ¼ mile east of the New Mexico line and 2 miles east of its 1 L. E. Elliott, recent south extension to Clear Fork production in the Drinkard field. The test is 1 W. E. Jones, in the center of the northwest quarter of Section 15, Block A-40, Public School Lands Survey. It is planned to explore the same horizon from which 1 Elliott is producing.

Fullerton field, Andrews County, had three completions this week, while North Cowden field, Ector County, and Sharon Ridge field, Scurry County, each had two. Fullerton field, Abell field, Pecos County, and Snyder field, Scurry County, each reported three new locations.

WEST TEXAS WILDCAT FAILURES

Ector County: Sinclair Prairie 1 Jessie M. Williamson, Sec. 40, Blk. 45, T-1-N. T&P Sur., 2 mi. W TXL pool, elev. 3,338 ft., Devonian 7,883 ft., Silurian 8,680 ft., Simpson 9,030 ft., Ellenburger 9,865 ft., TD 9,923 ft.

Yoakum County: Texas 1 W. K. Callahan, Sec. 308, Blk. D, J. H. Gibson Sur., 4 mi. N and 3 mi. W Plains, elev. 3,734 ft., San Andres 4,530 ft., dry, TD 5,519 ft.

SOUTHEASTERN NEW MEXICO

HOBBS.—Stanolind Oil & Gas Co. 1-S State, 32-22s-38e, is one of the best natural producers yet drilled in the Drinkard field in southeastern Lea County. On a 77-minute drill-stem test from 6,901-70 ft. in the Clear Fork, the well flowed 61 bbl. of oil in 60 minutes. Preparations were being made for completion. Neville G. Penrose, Inc. 1 Jones, 6-22s-38e, opens a deeper pay horizon for the east side of the Paddock area, southeastern Lea, which produces from the Holt zone. The test was perforated from 7,040-7,160 ft. in the Andrews zone, swabbed and kicked off, flowing 10 bbl. per hour. It was acidized with 2,000 gal., kicked off and flowed 180 bbl. into pits. After being turned into tanks, it flowed 35 bbl. of 38°-gravity oil. Amerada Petroleum Corp. 1-PB State, 16-23s-37e, northeast offset to the Grayburg discovery in the Penrose-Skelly field, Lea County, found water in that section and was drilled to 5,065 ft. It was perforated from 5,058-65 ft. and swabbed 36 bbl. of oil in 12 hours. It was fishing for packer.

Lea and Eddy counties each had one field completion. The Grayburg-Jackson field, Eddy County, and the Paddock field, Lea County, each reported two new locations.

SOUTHEASTERN NEW MEXICO WILDCAT FAILURES

Eddy County: Sunray 1-B Foster, 34-17s-31e, elev. 3,801 ft., dry, TD 4,516 ft.

Lea County: Olson-Blount Drilling 1 Caprock, 29-11s-32e, 6 mi. N Caprock field, elev. 4,414 ft., Glorietta 4,770 ft., dry, TD 5,115 ft.

EASTERN TEXAS

Humble's Franklin County Test Shows Water in Paluxy

DALLAS.—Humble Oil & Refining Co. 1 Gerow, John K Rogers Survey, wildcat 4 miles west and ¼ mile north of Talco, Franklin County, showed water in the Paluxy sand, drilled to 5,488 ft. in the Glen Rose section and is waiting on orders. Phillips Petroleum Co. 1 Craver, M. M. Long Survey, east offset to the discovery of the South Tyler field, Smith County, was waiting on cement to set after squeezing perforations from 9,894-99 ft. The well flowed some oil through the perforations but salt water broke through and it is to be reperforated. Sinclair Prairie Oil Co. 1 Schofner, William Dickerson Survey, wildcat in the Chapel Hill area, was setting 1¼-in. tubing after hooking up a blowout preventer. Total depth is 13,577 ft. in hard sand and shale. Delta Drilling Co. 1 Livingston, Nacogdoches University Survey, Travis Peak wildcat 3 miles southeast of Reilly Springs, Hopkins County, was drilling below 6,378 ft. in hard sand with no shows reported to present depth.

The Carthage field, Panola County, had nine completions this week. Carthage field, Pickton field, Hopkins County, Quitman field, Wood County, each reported two new locations.

MISSISSIPPI

Gilbertown, Ala., Field Adding Two New Producers

JACKSON.—Two new producers are in the process of completion in the Gilbertown field of Choctaw County, Alabama. Hunt Oil Co. 4 Boney, approx. SW NW 32-11n-4w, is pumping 90 bbl. per day of 20-gravity oil. Hunt Oil 5 Land, SE NE 31-11n-4w, is pumping 105 bbl. per day of oil.

Completions in the Mississippi fields totaled seven, including four oilers and three dry holes. Four wildcats are included in this figure, three of them dry and one a pool opener in Clarke County. Four new locations were announced this week, all field tries. Two wells will be drilled in the new Fayette field of Jefferson County, one in Hub field, Marion County, and one in Langsdale field, Clarke County.

MISSISSIPPI SUCCESSFUL WILDCAT

Clarke County: New oil pool—L. J. Rousell et al 1 Long Bell Petroleum Co., SE SW 10-2n-16e, pumped 37 bbl. of 13.6-gravity oil per day from Eutaw at 3,715-17 ft., TD 3,808 ft., Midway 3,153 ft., Chimney Hill 2,560 ft., Eutaw 3,625 ft.

MISSISSIPPI WILDCAT FAILURES

Greene County: Warren Petroleum 1 Smith, 660 ft. south and 1,980 ft. east of NW corner of 11-4n-6w, dry, TD 8,469 ft., Comanche 8,406 ft.

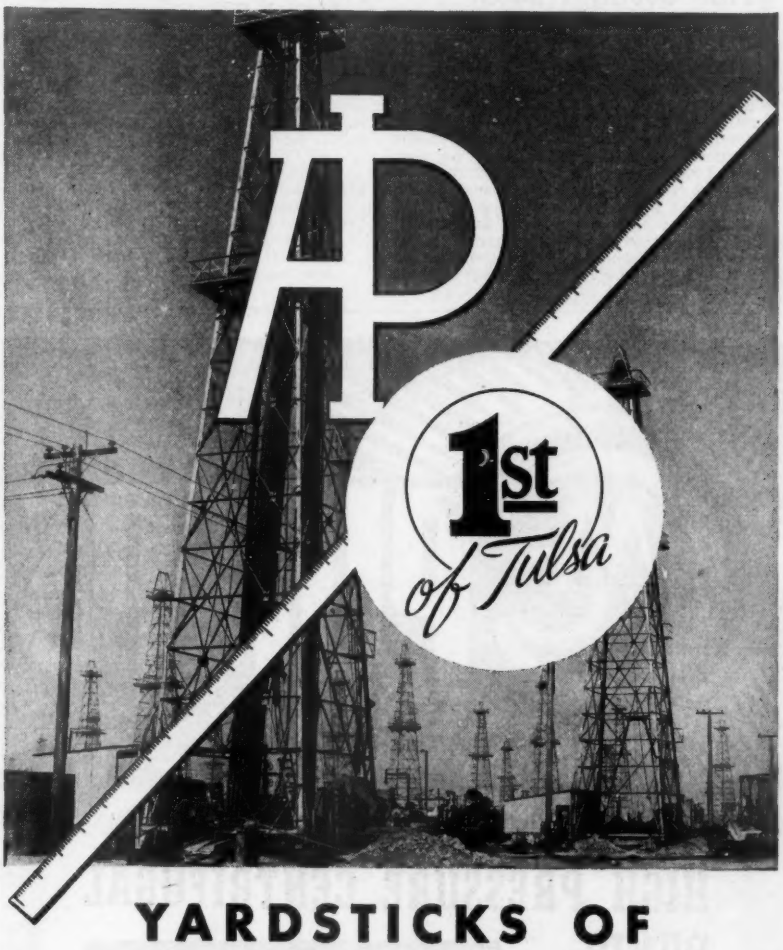
Jeff Davis County: Roeser & Pendleton et al 1 Fagan estate, 664 ft. north and 864 ft. west of SE corner of 24-6n-18w, dry, TD 10,080 ft., Massive sand 9,948 ft.

Jones County: Gulf Refining 1 Smith County Oil Co., 330 ft. south and 330 ft. east of NW corner of NE 19-9n-13w, dry, TD 8,658 ft., Comanche 8,577 ft.

FLORIDA WILDCAT FAILURE

Calhoun County: Pure Oil 2 St. Andrews Bay Property Co., 466 ft. north and 466 ft. east of SW corner of NW 25-1n-11w, dry, TD 4,457 ft.

Look Ahead With First National



YARDSTICKS OF *Experience!*

Through the American Petroleum Institute celebrating its Silver Anniversary, the combined experience of the entire Petroleum Industry is coordinated to standardize, conserve and increase efficiency . . . FIRST OF TULSA celebrating its Golden Anniversary Year is a partner of the Petroleum Industry since the discovery of oil in the Southwest, assembling information, simplifying Oil Financing.

THE FIRST NATIONAL BANK AND TRUST COMPANY OF TULSA

MEMBER FEDERAL DEPOSIT INSURANCE CORPORATION

KANSAS

Pratt County Wildcat To Be Dual-Completion

PRATT County has a dual discovery in Ed Swearer and Bridgeport Oil Co. 1 Brown, NW NW NW 25-29-13w, about 5 miles east of the Coates pool, nearest production. Perforations at 4,466-72 ft., in the Kinderhook, yielded 15 bbl. of oil per day, and 1,000,000 cu. ft. of gas, and the well will be dually completed. Lansing was topped at 3,881 ft., Heebner at 3,714 ft., Douglas at 3,751 ft., Lansing at 3,881 ft., Mississippi lime at 4,349 ft., Kinderhook at 4,383 ft., Simpson dolomite at 4,569 ft., and Arbuckle at 4,689 ft. Total depth is 4,789 ft., with 5-in. pipe set at 4,437 ft.

One and one-half miles southwest of the Derby gas field, Beech Aircraft Co. 2 McClelland, SW SW NE 6-29-2e, Sedgwick County, is completing as a large gasser. The well is making 11,000,000 cu. ft. of gas from the Lansing at 2,425-29 ft.

A show of free oil has been logged by Beech Aircraft 1 Hinkle, SW SE NW 6-27-2e, in Sedgwick County. Operator is running pipe to stop cavings higher in the hole. Mississippi lime was topped at 2,988 ft., and the free oil was logged two feet in the formation.

KANSAS SUCCESSFUL WILDCATS

McPherson County: New oil pool—Sharon Drilling 1 Crowther "A", NW SW NW 24-18-1w, potential 1,790 bbl. from Mississippi chert at 2,825-34 ft., TD 2,845 ft., Mississippi lime 2,816 ft., Mississippi chert 2,896 ft.

Sedgwick County: New oil pool—J. P. Gaty 1 Stollie, SW SE SW 22-26-2e, pumped 467 bbl. from Mississippi at 2,903-09 ft., TD 2,909 ft., Kansas City 2,450 ft., Mississippi 2,896 ft.

KANSAS WILDCAT FAILURES

Barber County: Lion 1 Lemon "D", SE NW NE 16-30-13w, dry, TD 4,737 ft., Arbuckle 4,656 ft.

Marion County: Tom Palmer 1 Batt, NE NE NE 20-19-4e, dry, TD 2,668 ft., Viola 2,627 ft.

Rush County: Great Lakes Carbon Co. 1 Kottal, NE NE NE 9-18-17w, dry, TD 3,611 ft., granite 3,610 ft.

Russell County: Ingling & Huber 1 Karst, NE NE NE 31-15-14w, dry, TD 3,399 ft., Arbuckle 3,359 ft.

Sumner County: Eldorado 1 Damitt, NW NE NW 13-33-2e, dry, TD 3,316 ft., Mississippi 3,253 ft.

Thomas County: Texas 1 Federal Land Bank, SW NE SW 7-8-35w, dry, TD 5,226 ft., Arbuckle 5,126 ft.

MC PUMPS

HIGH PRESSURE CENTRIFUGAL PUMP!

3" or 4" suction . . . 1½", 2", 3" or 4" discharge. Light weight . . . only 1500 lbs. . . . easily transportable . . . mounted on heavy oil field skids. Equipped with efficient Chrysler 6-cylinder engine. Available with exhaust primer. This high pressure Unit is especially desirable where oil or water is pumped for long distances. Write for special bulletin on this CMC High Pressure Centrifugal.

Oil Field Division

CONSTRUCTION MACHINERY COMPANY

Waterloo, Iowa

Houston Office: 1506 Esperson Building

Specializing in High Pressure Centrifugals . . . Dual Prime Centrifugals . . . Diaphragm Pumps and Electric Generating Plants for the Oil Field!

ILLINOIS

Mattoon Pool Supplies Best Well of the Week

MATTOON.—Twenty-eight oil wells and 25 dry holes were reported completed in Illinois in the past week. The oil wells averaged an even 100 bbl. per well in initial production.

The drilling campaign in Coles County resulted in seven completions during the week. Of these, three were oil wells with a combined initial production of 644 bbl. Four were dry holes which had been drilled in the hope of extending the Mattoon pool, or discovering new pools.

The best completion of the week in the state was Carter Oil Co. 1 E. Ganley, SW NW NW 2-11n-7e, in the Mattoon pool, which produced 417 bbl. in 24 hours from Cypress sand at 1,790-1,832 ft. and Aux Vases sand at 1,966-77 ft. It was shot with 100 qt. at 1,969-95 ft. A well that extended the Mattoon pool, or opened a new pool, was M. H. Richardson 1 William Powell, SE NE SE 10-12n-7e, which started off at 124 bbl. in 12 hours. It had been drilled to 2,007 ft. and plugged back to 1,818 ft. and shot with 40 qt. at 1,777-99 ft. in Cypress sand, topped at 1,750 ft.

The Clay City pool and the Golden Gate pool, both in Wayne County, were extended by wildcat tests.

The State Geological Survey's monthly report of developments shows two new oil pools, four pool extensions and three new pays discovered in October. The Gallagher and Parkersburg north pools were opened in Richland County, extensions were made to Clay City, Mattoon, North Boos and Cisne pools and new pays found were Lower O'Hara in the Phillipstown pool, Rosiclaire lime in the Stanford and Cowling pools.

Fifty-four new operations were started in the state in the past week including these wildcats: Texas Co. 1 G. Soldner, NE SE SE 36-5n-4e, Fayette County; National Associated 1 Phelps, NE NE SW 14-8s-5e, Saline County; T. L. Smith et al 1 Andres, NE SE NW 22-11n-7e, Coles County; K. & B. Drilling Co. 2 Bressenden, NE SE SW 16-3n-7e, Clay County; Oliver Leighty 1 Schrader, 992 ft. from S and 2,331 ft. from E line SE¼ 31-2n-12w, Wabash County.

ILLINOIS SUCCESSFUL WILDCATS

Coles County: W. H. Richardson 1 Powell, SE NE SE 10-12n-7e, TD 2,007 ft., PB to 1,818 ft. and Cypress sand shot with 40 qt. at 1,779-99 ft. Pumped 124 bbl. in 12 hours and later 400 bbl. in 24 hours. Cypress sand was logged at 1,750-59 ft., 1,773-90 ft. and 1,799-1,806 ft. Extends Mattoon pool.

Wayne County: Bell Bros. and N. V.

NO CLOGGED DISPENSERS

With Turco's Hand Cleaner

Handisan cuts grease, grime, stains—yet is milder than many toilet soaps

Because Turco Handisan is completely soluble it cannot form wasteful lumps to clog dispensers and stop up drains. It is an ideal mechanic's soap so gentle that it actually soothes bruised, chapped hands, yet so effective that it quickly removes grease, grime, ink and stains. It will not chap hands. Mildly but effectively antiseptic.

The secret is the perfect combination of granular toilet soap and an extremely fine, non-scratching and non-irritating abrasive powder. Write Turco, today

Send for free sample
Dept. OGJ-11

TURCO INDUSTRIAL CLEANING COMPOUNDS

TURCO PRODUCTS, INC. Main Office & Factory: 6135 S. Central Ave., Los Angeles 1
Offices & Factories · 125 W. 46th St.- Chicago 9 · 1606 Henderson St., Houston 1, Texas
New York Office: 415 Greenwich St., New York 13 - Offices & Warehouses in All Principal Cities

Manufacturers of Oil Field Cordage for Many Years

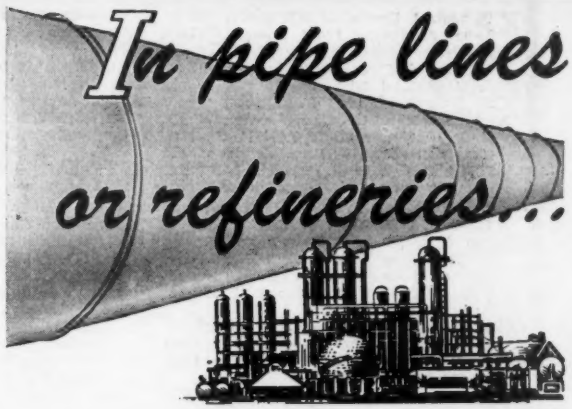
Distributors stocks at principal points

Write us for booklet "CARE SAVES ROPE" and W.P.B. Conservation Literature

ST. LOUIS CORDAGE MILLS

11th & Lafayette Streets, St. Louis, Mo.

"YOU CAN'T BUY MORE DEPENDABLE BRANDS"



GOULDS PUMPS

Can take it!

Day in and day out, Goulds Triplex Double-acting Reciprocating Pumps handle as many as 4,700 to 55,000 barrels every twenty-four hours and at pressures up to 1,000 P.S.I. To build pumps for such service requires a thorough knowledge of pump design and engineering.

Few, if any, pump manufacturers can match Goulds record. It's important to you because when you are handling oil, the pump must first be safe to use and second, dependable in continuous, heavy-duty service. As pump specialists for 97 years, Goulds has developed standard lines of reciprocating, rotary and centrifugal pumps from which you can usually select *the* pump for *the* job. To save time . . . to save money . . . bring your pump problems to pump headquarters. Literature on request.

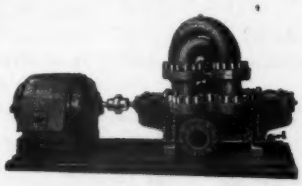


Fig. 3365—Goulds High Pressure centrifugal pump designed for heavy-duty, 24-hour service.

Goulds PUMPS, INC.

the PUMP FOR the JOB **SENECA FALLS, N. Y.**

Duncan 1 Leach, C NW¼ NW SE 9-2s-9e, producing from Lower O'Hara lime at 3,302-11 ft. and Rosiclaire lime at 3,329-42 ft., both formations acidized. IP 122 bbl. per day, TD 3,407 ft. Extends Golden Gate pool.

A. J. Slagter 1 Groff, SW SW NW 31-2n-9e, Rosiclaire lime 3,064-71 ft., McClosky lime 3,079-82 ft., acidized, TD 3,090 ft., IP 260 bbl. of oil in 24 hours. Extends Clay City consolidated field.

ILLINIOS WILDCAT FAILURES

Clinton County: J. C. Powell and Rea 1 C. A. Allen, SW SW NW 5-2n-2w, dry at 1,311 ft. Glen Dean 880 ft. Cypress 1,070 ft., Benoist 1,185 ft., Aux Vases 1,301 ft.

Coles County: E. P. Jarvis 1 McIntyre, SW SW NW 20-12n-8e, dry at 2,188 ft. Glen Dean 1,808 ft., Barlow 1,891 ft., McClosky 2,166 ft.

Kingwood 1 F. E. Wilson, SW SW SW 15-11n-7e, dry at 2,325 ft. No log.

Henderson County: Northern Ordnance 1 C. Pendarvis, C NW NW 17-9n-4w of 4th principal meridian, dry at 446 ft.

Logan County: Lee Weiner 1 Brittan, SW SW SW 22-14n-3w, dry at 494 ft.

Richland County: C. R. Croft 1 Boley, NW NE SW 7-2n-14w, dry at 3,291 ft. Menard 2,492 ft., Barlow 2,890 ft., Aux Vases 3,162 ft., Ste. Genevieve 3,227 ft.

Washington County: Glenwood Oil 1 Morticio, NE SW NW 12-2s-1w, dry at 2,207 ft. Menard 1,201 ft., Cypress 1,658 ft., Benoist 1,784 ft., Aux Vases 1,867 ft., Fredonia 1,958 ft.

Wayne County: Fisher Oil 1 Corbett, NE SE NW 25-2s-9e, dry at 3,345 ft. Lower Kincaid 3,254 ft., Cypress 2,942 ft., Benoist 3,109 ft., Aux Vases 3,227 ft., McClosky 3,338 ft.

Ben Lucas 2 Rae Lucas, SW SW NE 7-1n-6e, dry at 3,137 ft., McClosky lime at 3,052-58 ft.

White County: C. R. Croft 1 Ford, SW NW NE 9-7s-10e, dry at 3,055 ft. Upper Kincaid 1,770 ft., Cypress 2,616 ft., Benoist 2,702 ft., Aux Vases 2,894 ft., McClosky 2,975 ft., St. Louis 3,052 ft.

GATKE Brake Blocks Pay Double NOW!

The *Extra Performance Qualities* of GATKE Brake Blocks *are life savers* in these days of critical man power and material shortage.

The *great holding power* with *smooth, non-grabbing action* at all depths gets the job done *quicker* with reduced strain on men and equipment.

Long wear life with reduced flange wear facilitates *continuous* operation and *avoids maintenance.*

Avoid substitutes. Your Rig Manufacturers have GATKE Brake Lining that's engineered for the job.

GATKE Brake Blocks are made in many types to meet all service requirements of Oil Field Equipment.

Their Extra Performance Qualities result from nearly 30 years specialized development to meet changing requirements of Oil Field Service.

When your rig is GATKE-equipped, you have the best.

GATKE CORPORATION
228 N. LaSalle St. Chicago 1, Ill.

N. CENTRAL TEXAS

Young County Producer Flows 37 Bbl.

WICHITA FALLS.—Walter Gant 2 Jarrell, D. Franklin Survey, 4 miles southwest of Graham, Young County, is a producer from the Marble Falls in the Dean pool which produces from the Caddo. It flowed 37 bbl. of 39.2°-gravity oil in 6 hours through ½-in. tubing choke. Pay was topped at 4,150 ft. with total depth of 4,180 ft. Gas-oil ratio was 1,000 to 1. Panhandle Producing & Refining Co. 1 Graham, D. H. Pruitt Survey, wildcat 4 miles west of Eliasville in southern Young, took a 30-minute drill-stem test in the Caddo lime from 3,469-79 ft. and recovered 40 ft. of gas-cut drilling mud. It was drilling below 3,744 ft. in lime. Robertson Drilling Co. 1 Burch, Block 466, TE&L Survey, wildcat 5 miles northwest of Graham in central Young, was drilling below 4,740 ft. in Mississippian.

Continental Oil Co. 1 Cox, Lot 32, Block 1, Henderson County School Land Survey, wildcat 2 miles north of Gibtown, southeastern Jack County, topped the Caddo lime at 4,040 ft. It is drilling ahead at 4,218 ft. in shale with lime streaks. Continental 1 Donnell, Block 65, Freestone County School Land Survey, southeastern Clay County wildcat 2 miles south of Vashti, is dry at 7,020 ft. in lime after drill-stem test was run from 5,976-6,020 ft., plugged-back depth.

Archer, Throckmorton, Wichita and Young counties each had four field completions this week. Wichita County reported 13 new field locations, Archer County 9 and Montague County 5.

NORTH CENTRAL TEXAS SUCCESSFUL WILDCAT

Jack County: New oil pool—Hanlon-Buchanan 1 Whittsitt, Sec. 2, Wm. McElroy Sur. A-1475, 2½ mi. NE Hoefle field, elev. 1,005 ft., pumped 40 bbl. day, perf. 5,173-81 ft. Caddo, TD 5,181 ft.

NORTH CENTRAL TEXAS WILDCAT FAILURES

Clay County: S. D. Johnson 1 Mrs. I. Newton, Sec. 2,673, TE&L Sur., 5½ mi. N Antelope, dry, TD 3,665 ft.

Childress County: Ohio 1 L. A. Gibson, Sec. 484, Blk. H, W&NW Sur., 5½ mi. S and 4½ mi. E Childress, elev. 1,805 ft., dry, TD 7,374 ft.

Cooke County: Cox & Hammon 1 Davis, B. C. Johnson Sur., 4 mi. E Sivell's Bend pool, elev. 794 ft., dry in Strawn, TD 7,732 ft.

B. W. Fitzgerald 1 Mrs. J. B. McLaughlin, Thos. Mathews Sur. A-710, 1 mi. S and W Valley View, Ellenburger 1,509 ft., dry, TD 1,551 ft.

S. D. Johnson and Alco Valve Co. 1 Mrs. Allie Cauldwell, W. Thomas Sur. A-1025, 1½ mi. S and 2 mi. W Myra, dry, TD 1,780 ft.

S. W. Petre 1 Wm. McKaig, A. C. C. Bailey Sur., 2½ mi. E and ½ mi. S Gainesville, dry in Strawn, TD 2,429 ft.

Wichita County: Scott Bros. 1 Mackechrey, Lot 18, Leag. 2, Denton CSL Sur. A-57, 8 mi. W and 4 mi. S Wichita Falls, dry, TD 1,255 ft.

Wichita Engineering 1-A Obenhaus, Lot 323, Waggoner Colony Subd., 5 mi. E and 3 mi. N Electra, dry, TD 2,152 ft.

Frank Wood 1 Ross W. Porter, Sec. 32,

10th Anniversary

NOX-RUST

The Master RUST Preventive

A decade ago this organization of industrial engineers and chemists began a collaboration that constantly is increasing its momentum and usefulness to American industry.

After a strenuous war service, NOX-RUST now is bending its efforts to encompass the widely-varied rust-proofing needs of post-war industry.

Tell us what you want to rust-proof — in processing — in storage — in transit — and we'll submit a

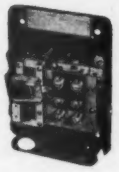
FREE SAMPLE

George A. Paubert
President

NOX-RUST CHEMICAL CORPORATION
2461 S. HALSTED ST.
CHICAGO 8

★MERCOID CONTROLS★
FOR HEATING, AIR CONDITIONING, REFRIGERATION, AND VARIOUS INDUSTRIAL APPLICATIONS

TEMPERATURE CONTROLS



MERCOID RELAYS

EXPLOSION PROOF PRESSURE CONTROL

MERCURY SWITCHES

LIQUID LEVEL CONTROLS

MERCOID HAS WHAT EXPERIENCED ENGINEERS WANT IN AN AUTOMATIC CONTROL

1. Designed for positive safety—*the prime purpose of a control.*
2. Built for years of dependable performance—*a very desirable feature.*
3. Simplified for ease of installation—*appreciated by the trade.*
4. Convenient facilities for making understandable adjustments—*no time lost in calculating or guesswork.*
5. The only 100% Mercury Switch Equipped Control Line—*which means that all "makes" "and breaks" in the electrical circuit are hermetically sealed, therefore immune to dust, dirt, corrosion, open arcing, pitting, or sticking of contacts—all common causes of contact trouble. Mercoid Switches provide an electrical contact that will give millions of perfect operations.*

The above facts merit your consideration. For detailed information see Mercoid catalog No. 600.

THE MERCOID CORPORATION • 4201 BELMONT AVENUE • CHICAGO, ILLINOIS

This WISCONSIN-POWERED PUMP

Never "Looked Back" Once!

Here is a field gathering oil pumping unit that can "take it" . . . and keep on looking ahead for more! It consists of a Wisconsin VE-4 Air-Cooled Power Unit, direct-connected to a rotary pump through a Clutch Reduction. It handles 90 barrels per hour at 300 lbs. discharge pressure, operating in the South Hickory Creek field in Oklahoma . . . in the service of Stanolind Pipe Line Company.

This unit, at last report, had been operating almost a year out there in the open, in all weather! . . . without even the slightest adjustment on the engine!

You can't go wrong if your equipment is Wisconsin-powered.

WISCONSIN MOTOR Corporation
MILWAUKEE 14, WISCONSIN
World's Largest Builders of Heavy-Duty Air-Cooled Engines

WRITE TO HARLEY SALES CO.
510 Atlas Building, Tulsa, Oklahoma
M & M Building, Houston, Texas
Oil field distributors for Wisconsin Engines and all types of utility units.

PAGE FENCE - Since 1883

• AMERICA'S FIRST WIRE FENCE •

You Can Order Your Fence Now

● Because of the importance of property protection, war restrictions on chain link fence are among the first to be lifted. Many will want the fence that was denied them, as they have wanted other things so long scarce or unobtainable except on highest priorities. It will take months to catch up with demand. Therefore, it is advisable to place your order NOW for long-lasting Page Fence. The Page Fence Association member nearest you will submit cost estimates and book your order. If you do not know his name, write or wire to the Association office in Atlanta, Bridgeport, Chicago, Denver, Los Angeles, Philadelphia, Pittsburgh, New York, San Francisco, or Monessen, Pennsylvania.

PRODUCT OF PAGE STEEL & WIRE DIVISION—AMERICAN CHAIN & CABLE, BRIDGEPORT, CONN.

"C" VALUE Reduced to 1/5 "C" VALUE

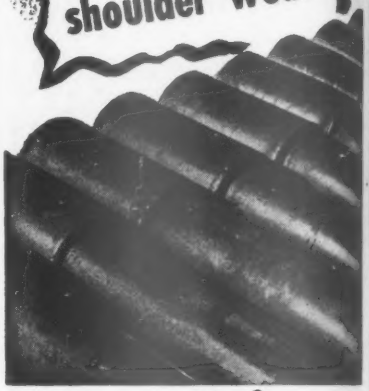
RESTORED IN FULL BY FLEXIBLE

ONE OF AMERICA'S largest oil refineries forgot this 30" pipe line until its "C" value was reduced from its original 132 to 24. How long this capacity has been reduced we do not know. But, we do know that its original capacity has been restored in full . . . that pumping costs are down while volume pumped is up each in proportion . . . and the costs for cleaning were infinitesimal in comparison to the wasted power or the cost of replacing the pipe.

What is the condition of your pipe lines? Can you afford to guess? Write today! Have Flexible check your pipe lines and estimate the cost of restoring their "C" value.

FLEXIBLE SEWER-ROD EQUIPMENT CO.
Pipe-Cleaning Division
9059 VENICE BOULEVARD • LOS ANGELES 34, CALIF.

Tube Borium HALTS shoulder wear

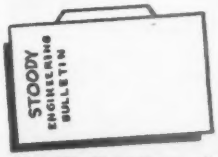


Doubles tool joint life

For fifteen years Tube Borium has been used on drilling bits to increase cutting speeds and drill more out-to-gauge hole. Now you can use this same alloy to greatly prolong the life of your tool joints!

An exceedingly small quantity of Tube Borium welded in a ring around the shoulder not only doubles tool joint life—even under the toughest operating conditions—but maintains over all joint strength and correct elevator contour. Applications are economically made on both new and resleeved joints.

APPLICATION: Accepted method of application is to under-cut new or resleeved joints at the shoulder to form a recess ⅛" deep by 1½" wide. The recess is then filled by welding in with ⅛" Electric Tube Borium to form the wear resistant inlay.



Write for this special Stoody engineering bulletin describing in detail hard-facing procedures on tool joints—no obligation.

STOODY COMPANY
1138 WEST SLAUSON, WHITTIER, CALIF.

STOODY HARD-FACING ALLOYS
Retard wear . . . Save Repair

Blk. 5, H&TC Sur., 1 mi. W and 3 mi. S Electra, dry, TD 2,000 ft.

WEST CENTRAL TEXAS

ABILENE.—W. R. Skeen et al 1 Hatchett, Block 33, Orphan Asylum Land, wildcat 14 miles southwest of Breckenridge, promised Ellenburger production for Stephens County when it flowed 20 bbl. per hour after acidization. It was perforated with 14 shots from 4,215-18 ft. Nearest production is from the Caddo lime 2½ miles southwest.

Carl Hovgard 1 Hamp Campbell, Section 6, Block 18, T&P Survey, wildcat 1 mile northwest of Blair, northwestern Taylor County, had a showing of free oil at 2,500 ft. but the hole began caving before a test could be made. Casing was being underreamed to the top of the lime for a test. Rhodes Drilling Co. of Abilene has staked 1 W. D. Swann, an Ellenburger wildcat in Taylor County 12 miles northwest of Merkel and near the Fisher County line. It is 467 ft. from the south line and 990 ft. from the west line of I. Miley Survey No. 281.

Taylor County had two field completions. Reddin field, Taylor County, reported two new locations.

WEST CENTRAL TEXAS WILDCAT FAILURES

Coleman County: McElreath, Suggett & Davidson Drilling 1 W. C. Bozeman, N. R. Tatem Sur. No. 741, 4 mi. SE Coleman, elev. 1,623 ft., dry in Fry, TD 2,063 ft.

Jones County: Humble 1 D. W. Hawthorne, M. R. Longario Sur. No. 258, 2 mi. S Truby, elev. 1,682 ft., dry in Canyon, TD 3,706 ft.

OKLAHOMA

Two Wildcats Take On New Life in Canadian County

CARTER Oil Co. opened its second pool in McClain County, Oklahoma, in the past week when its 1 Mottinger, C NW NW 5-6n-3w, north of the town of Criner, made two four-hour flowing tests through drill-stem, making, 315 bbl. of oil in the first four hours and after a three-hour intermission, 290 bbl. in four hours. Total depth of the hole is 10,844½ ft. with pipe set at 10,812 ft. Tests were made with ½-in. choke on bottom and ¾-in. choke on top. Gas oil ratio 742 ft. to 1 bbl. of oil. Gravity 40.7 degrees, corrected. In the Washington field, also a Carter discovery, the company's 1 Autry, C SE SW 9-7n-3w, total depth 10,631 ft., flowed 59 bbl. of oil on a 3-hour drill-stem test.

Fox & Fox 1 Simpson, C SE SW 9-14n-5w, a wildcat about 3½ miles west of production in the West Edmond field in Canadian County, which was supposed to be a failure last August, but not abandoned, has shown indications of substantial production from Bartlesville sand at about 7,100 ft. Last week it was opened and flowed an estimated 80 bbl. in 45 minutes. Then through ¼-in. choke, it flowed 35 bbl. in 1 hour and the following day 40 bbl. in 1½ hours, flow ceasing at the end of that time. It will be given additional tests. Ace Gutowsky's 1 Hoover C SE SW 14-14n-5w, 1½ miles from production, which was about to be abandoned, was given a new life as drilling was resumed at 7,176 ft. after Bartlesville sand was found dry at about 7,000 ft.

The Bethany area of the West Edmond field, at the close of the week had 10 completed wells, including 7 oil wells, 2 gas-distillate wells and a dry hole. This part of the pool is in Township 12n-4w, Oklahoma County.

OKLAHOMA SUCCESSFUL WILDCAT

Garfield County: New oil pool—Gulf 1 Decker, SE SW NW 12-20n-4w, pumped 80 bbl. of 38.9-gravity oil per day from second Wilcox at 6,095-6,119 ft., TD 6,156 ft., Viola 5,867 ft., Deese 5,899 ft., Wilcox 5,983 ft., second Wilcox 6,078 ft.

OKLAHOMA WILDCAT FAILURES

Bryan County: Atlantic 1 Brown, NW NW SE 16-8s-8e, dry, TD 6,676 ft.

Coal County: Skelly 1 Mayer, SE SE NW 33-1n-10e, dry, TD 4,621 ft.

Garvin County: Ohio 1 Chisholm, SW NW NW 13-3n-1e, dry, TD 3,858 ft., Oil Creek 3,843 ft.

Greer County: Stephens Petroleum 1 School Land, NW NW SE 16-7n-21w, dry, TD 1,452 ft., granite 1,380 ft.

Logan County: Four States 1 Bowen, NW NW NW 36-17n-3w, dry, TD 4,796 ft., Layton 4,552 ft.

Ace Gutowsky 1 Taylor, NW SE 6-18n-2w, dry, TD 6,166 ft., second Wilcox 6,030 ft.

Payne County: Quinton Little 1 Freeman, NW NE 1-17n-2e, dry, TD 4,809 ft., second Wilcox 4,804 ft.

Seminole County: W. A. Delaney, Jr., 1 Huckleberry, NW NW SE 6-5n-8e, dry, TD 3,250 ft., second Cromwell 3,220 ft.

CANADIAN FIELDS

Turner Valley Field Adds Two Producers

CHATHAM.—In Turner Valley, two small producers have been completed in the Madison limestone. In the south area, Mercury-Mill City 1, LSD 10, 16-18-2w5, with Madison at 6,437-6,891 ft. had around 50 bbl. after acidizing. In West Central Turner Valley, Royalite 83, LSD 13, 19-19-2w5, an east flank test, made around 56 bbl. initial production, with Madison at 6,874-7,113 ft. Seven other wells are drilling, two finished and three testing.

Steveville.—In the Steveville-Princess field, eastern Alberta, National-Empire 1, LSD 10, 34-19-22w4, finished at 3,288 ft. and blew in with 20,000,000 to 30,000,000 cu. ft. of gas from the Sunburst. Gas was cemented off to test good oil shows. Peerless Oils 1, LSD 4, 18-20-11w4, total depth 3,184 ft., has shut off gas flow and will go on the pump with production, estimated at 45 bbl. of 26 to 27-gravity crude, from an horizon between shale breaks at 3,183 ft. Patricia-C.P.R. 1, LSD 4, 6-20-12w4, total depth 4,313 ft., has plugged back to test Sunburst sand.

Hay Lake.—On the Hay Lake Dome close to the Montana boundary, Admiral-British Dominion 1, LSD 7, 22-1-17w4, total depth 3,094 ft., is making 85 bbl. daily with 62 bbl. oil and 23 bbl. water. A second test is drilling.

Sullivan Creek.—Following two unsuccessful tests, the potential southerly extension of Turner Valley in the Sullivan Creek area will be tested by Phillips Petroleum, following inspection of the field by M. R. McArthur, head of the Rocky Mountain section of the company.

Kinsella.—Systematic testing for oil is being undertaken by Imperial Oils, Ltd. in the area east of the Kinsella field, in east central Alberta, where Imperial-Kinsella 1 is starting in LSD 11, 20-47-9w4. The Kinsella gas field is an extensive source of supply for Northwest Utilities of Edmonton and extensive drilling for gas in the eastern part of the field encountered some oil showings.

Lloydminster.—In the Lloydminster field, east central Alberta, S.A.C. (Alberta) 2, LSD 1, 12-49-1w4, finished at 1,874 ft. and had initial production of 24 bbl. of 14-gravity oil. Two new wells are starting.

ALBERTA WILDCAT FAILURE

Northern Alberta: Cameron-Helena 1, LSD 4, 24-52-12w4, TD 2,787 ft., dry.

ROCKY MOUNTAIN

Embar Production Found On Zimmerman Butte

DENVER.—The outstanding development of the week in Rocky Mountain area was a discovery in the Embar on Zimmerman Butte, on the southern rim of the Big Horn Basin, Hot Springs County, Wyoming, in Pacific Western Oil Corp. et al 1 Pacific Western, NW SW SW 36-44n-93w. It had the top of the Embar at 4,309 ft., top of saturation at 4,312 ft., and drilled to 4,332 ft., total depth. After setting the 7-in. at 4,310 ft., and drilling plug, it swabbed at an estimated rate of 50 bbl. per hour for the first 4 hours, the oil going into the pits. Then it began flowing 10 bbl. per hour, and gradually increased to 14 bbl. per hour when storage was full and the well was shut in for tankage. The oil is 25.2 gravity, with less than 1 per cent of water and only an odor of sulfur.

Eastern Colorado wildcats.—An important wildcat play in Colorado, east of the mountain range, is developing rapidly. The most critical is Skelly Oil Co. 1 Hankins, SE SE NW 34-33n-44w, Baca County, which is reported shut down at 6,360 ft. after having topped the Arbuckle at around 6,100 ft. Rumors, none of which have been confirmed, are to the effect that saturation was encountered in the Kansas City lime.

Pacific Western Oil-Frontier Refining 1 Government, SW NW SE 12-26s-50w, Caddoa District, Bent County, is drilling below 3,880 ft.

Colorado Wildcat Oil Co. 1 Clark, SW SW SW 2-18s-51w, Haswell District, Kiowa County, has cemented the 5½-in. at 2,060 ft., and is preparing to drill plug and test a show of oil reported in the Lyons formation of Permian age.

Oriental Refining Co. 1 Gallagher, NW NE SW 9-1n-70w, a deep test to the Muddy in the old Boulder field, had the top of the Muddy sand at 4,640 ft., with a good show of oil after drilling 2 to 3 ft. in the sand, and is trying to make a test, but is having trouble because hole is down to 3 inches.

Show of oil at Skull Creek.—Morton & Seigel 1 State, SW NE 16-44n-62w, Skull Creek district, Weston County, Wyoming, has a showing for a commercial well in the Muddy sand at 3,342-68 ft., and is bailing for a test. It is ½ mile from a well drilled 22 years ago by Midwest Refining Co. which had a good show and was abandoned in the Lakota at 3,592 ft.

New operations.—Seventeen new operations were reported for the week, of which six are in Colorado, seven in Wyoming, and four in Montana. Of that total, six are wildcats, two in Colorado, and four in Wyoming.

Completions.—Eight wells were completed of which five were oil wells with an initial production of 756 bbl. per day, one was a gas well and two were dry holes. Four of the five oil wells were in Wyoming, all development wells, and one in Montana, a wildcat for 20 bbl. per day.

COLORADO WILDCAT FAILURE

Ojo-Oakview, Huerfano County: Gled Oil 1 Campbell, SE NW NW 3-29s-69w, TD 647 ft., dry.

MONTANA SUCCESSFUL WILDCAT

Utopia, Liberty County: Texas 1 Government, NW SE SW 15-33n-4e, TD 2,544 ft., Madison 2,503 ft., pumped 20 bbl. oil and 60 bbl. water first 24 hours, 24 bbl. oil and 44 bbl. water second 24 hours.

NORTHWEST NEW MEXICO WILDCAT FAILURE

Santa Fe County: Richfield Oil Corp. 2 Federal-Lee, SW SW 14-14n-11e, TD 2,715 ft., dry in granite.

PENBERTHY
"REFLEX"
WATER GAGE SET

For oil field, locomotive type and marine boilers. Water shows black — steam shows white; the water level is unmistakable. U-Bolt construction is strongest and simplest to service. Glass replaced by simply removing nuts on face of gage . . . unnecessary to work between gage and boiler. Conforms with A.S.M.E., Federal and State requirements when used for pressures specified by their respective codes.

This is one of the complete line of Penberthy gages that meet every liquid level gage requirement.

PENBERTHY INJECTOR CO.
DETROIT, MICH. Canadian Plant WINDSOR, ONTARIO

FOR CHANGING FORMATIONS

ZUBLIN
DIFFERENTIAL BITS

Four different cutting actions directed at bottom and sides of hole. Features safety and simplicity, trouble free drilling. See Composite Catalog or Bulletin and Prices upon request.

UNIVERSAL ENGINEERING CO.
OFFICE AND FACTORY
2369 EAST 51st ST. • LOS ANGELES 11, CALIFORNIA
BRANCHES: HOUSTON, TEXAS • LAKE CHARLES, LA.
BAKERSFIELD, VENTURA AND AVENAL, CALIFORNIA

Among the Drilling Contractors

Muskegon Development Co. has the contract for Gulf Refining Co. 1 Richter, N/2 NW SW 36-15n-4e, in the Kawkawlin field of Bay County, Michigan.

Jeff Dye is the contractor for Ohio Oil Co. 1 Hernasco Corp., 510 ft. south and 660 ft. east of NW corner of 19-23s-18e, in Hernando County, Florida.

Turner Drilling Co. will drill the Pure Oil Co. 1 Heber, N/2 SW SW 6-18n-4w, in the Harrison field of Clare County, Michigan.

Cook Drilling Co. will drill the Skelly Oil Co. 1 Lightsey, SW SW NW 18-1n-13e, in the East Heidelberg field of Jasper County, Mississippi.

E. W. Leeder is the contractor for S. L. Findley 1 Robert Kaylor Commission, SW SW SW 1-1n-14w, a wildcat in Allegan County, Michigan.

Can-Tex Drilling Co. of Calgary has the contract with California-Standard Oil Co. for Conrad-Province 73-33-B in LSD 5, 33-5-15w54, recently started in the Conrad field, southern Alberta.

W. C. Taggart will drill two Clare County, Michigan, tests. One is Consumers Power Co. S-41 Smith-Consumers Power, NE 20-20n-5w, and the other is Consumers Power Co. 133 Payne-State, SE 35-20n-6w.

O. H. O'Neal is the contractor for Alpha Oil Co. 1 Harris, NE SE NE 25-3n-4e, a wildcat in Livingston County, Michigan.

E. M. Shields is the contractor for Socony-Vacuum Oil Co., Inc., 1 Towle et al, NE SE NW 14-12n-6w, in the Belly Achers field of Montcalm County, Michigan.

Muskegon Development Co. will drill Carter Oil Co. 1 Neumann, NE SE NE 21-14n-18w, a wildcat in Oceana County, Michigan.

Gordon Rotary and **Muskegon Development Co.** are contractors for United Drillers and Producers, Inc., A-1 State-Foster, NW NW NE 33-24n-2e, in the Rose City field of Ogemaw County, Michigan.

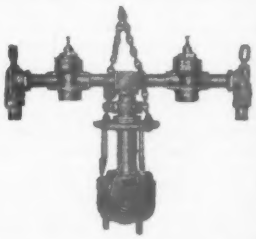
Conway Drilling Co. has the contract for Lisbon Gasoline Co., Inc., 1 Wynn et al, 150 ft. south and 330 ft. west of NE cor. 22-17n-9w, a wildcat in Washington County, Mississippi.

Acme Drilling Co. will drill Sohio Petroleum Co. 1 Tousley, NW NW NE 9-9n-5w, a wildcat in Montcalm County, Michigan.

M & M Drilling Co. is drilling surface hole for Gulf Refining Co. 1 Myers et al unit "A," 1,915 ft. north and 2,282 ft. east of SW corner of 6-10n-10w, in West Heidelberg field of Jasper County, Mississippi.

Newell & Chandler of Calgary have finished the drilling of Pacific Petroleums 9 in LSD 11, 35-19-3w5, in the West-Central section of Turner Valley. The test finished at 8,518

MACCLATCHIE
Quick Change
Cement Head



Used for "washing-in" casing as well as for cementing. Can be installed or removed in less than a minute even while the pipe is in motion, eliminating the danger of freezing. Fluid tight seal insured, as the slips and rubber packer grip tighter as pressure increases. Used by all cementing companies and major operators throughout the world. Write for your complete catalog of "MacClatchie Quality Products."

MACCLATCHIE MFG. CO.
P. O. Box 430, Compton, Calif.
Mid-Continent Distributor: HAKE TOOL CO., Houston. *Rocky Mountain District:* MOUNTAIN SALES & SERVICE CO., Casper, Wyo. *Canada:* GEORGE KIPP (ALBERTA) LTD., Calgary. *Export:* ELMER R. SMITH, 617 So. Olive St., Los Angeles 14, Calif.

WORTH WAITING FOR BUT NO WAITING IS NECSSARY

'BESTOLIFE — the Lead Seal Joint Compound used successfully in the Drilling and Refining Industries for years — is immediately available through more than 100 distributors in the U.S.A. Any priority rating will do.

Your nearest supply house field store probably has 'BESTOLIFE in stock for immediate delivery. Use 'BESTOLIFE — it's BETTER!

EXPORT: THE NATIONAL SUPPLY CORP., 30 ROCKEFELLER PLAZA, NEW YORK

I. H. GRANCELL
1601 EAST NADEAU STREET
LOS ANGELES 1, CALIFORNIA

HOW TO MAKE A LITTLE STEEL GO A LONG WAY

A 2", 6000 lb. test, ring joint flanged union weighs 54 lbs. . . . enough steel to make nearly five 2", 6000 lbs. test, UNIBOLT Couplings! And UNIBOLT Couplings have a higher safety factor.

UNIBOLT
(TRADE MARK REGISTERED U. S. PATENT OFFICE)
THE ONE BOLT COUPLING

THORNHILL-CRAVER COMPANY • HOUSTON

LOANS

ON INTERESTS IN
OIL AND GAS PROPERTIES

David Donoghue
Fort Worth Nat'l Bank Bldg.
Fort Worth 2, Texas

ft., 172 ft. in Madison limestone, with a good producer indicated.

Penrod Drilling Co. is drilling surface hole for H. L. Hunt 2 Long Bell Petroleum Co., 990 ft. north and 330 ft. east of SW corner of 29-1n-18e, in the Langsdale field of Clarke County, Mississippi.

Goll, Graves & Mechling, Inc., has the contract for Basin Oil Co. and Don Rayburn A-1 Howosielski, SE NE SE 8-19n-4e, in the Deep River field of Arenac County, Michigan.

CALENDAR

December

Rocky Mountain Oil and Gas Association, annual meeting, Townsend Hotel, Casper, Wyo., December 7-8.

Independent Natural Gas Association of America, annual membership meeting Baker Hotel, Dallas, December 10.

Michigan Oil and Gas Association, annual meeting, Mt. Pleasant, December 3.

Interstate Oil Compact Commission, Wichita, Kans., December 13-15.

1946

January

FPC regional hearing in natural-gas investigation, Houston, January 28.

Independent Natural Gas Association of America, annual membership meeting, Texas State Hotel, Houston, January 28.

February

American Welding Society, national meeting, Hotel Cleveland, Cleveland, February 4-7.

Iron and Steel and Institute of Metals divisions, American Institute of Mining and Metallurgical Engineers, national meeting, Statler Hotel, Cleveland, February 4-8.

American Society for Metals, annual convention (postponed from 1945), Statler Hotel, Cleveland, February 4-8.

FPC regional hearing in natural-gas investigation, Biloxi, Miss., February 11.

FPC regional hearing in natural-gas investigation, Chicago, February 19.

American Society for Testing Materials, spring meeting, Pittsburgh, February 25-March 1.

Exposition of Chemical Industries, twentieth exposition, Grand Central Palace, New York, February 25-March 2.

March

FPC regional hearing in natural-gas investigation, Charleston, W. Va., March 19.

Southern Gas Association, annual convention, Galveston, March 21-22.

April

American Association of Petroleum Geologists, annual meeting, Stevens Hotel, Chicago, April 2-4.

Natural Gasoline Association of America, annual convention, Baker Hotel, Dallas, April 17-19

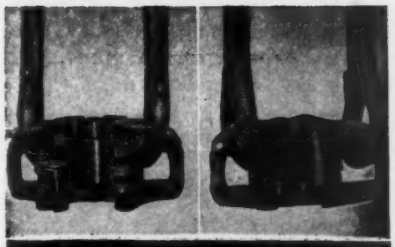
National Petroleum Association, semi-annual meeting, Hotel Cleveland, Cleveland, Ohio, April 18-19.

May

National Association of Corrosion Engineers, annual meeting, President Hotel, Kansas City, Mo., May 7-9.

June

American Society for Testing Materials, annual meeting, Buffalo, June 24-28.



In Either Open or Closed Position

BJ "AA" ELEVATORS ARE REALLY BALANCED

By incorporating a newly devised roller type balancing cam in BJ "AA" Elevators the work of the derrick man is made much easier. Rated at 300 tons, with a safety factor of four to one, this elevator is made of high alloy steel—fully heat treated—flame hardened on the top bore to minimize upsetting —and is equipped with an unusually sturdy latch. Ask the BJ man or your supplier.

BYRON JACKSON CO.
Houston • LOS ANGELES • New York

DAWSON & CORBETT

Pipe Stringing

I. C. C. Authority — heavy hauling — Colorado, Wyoming, Montana, North and South Dakota. Pipe lining — building & construction — derrick skidding. Trucks — tractors — trenchers and welders.

Baroid products in stock at Riverton and Rawlins, Wyoming, and Craig, Colorado.

DAWSON & CORBETT
RAWLINS • Box 288 • WYOMING

XUM

PERSONALS

Hardwick Goes to Higher Post in Ohio Oil Co.

CHARLES Z. HARDWICK, since 1934 assistant manager of The Ohio Oil Co.'s refining and marketing department, has been promoted to manager and elected a vice president, following the recent retirement of C. L. Fleming, who had held these posts.

Hardwick started his career with Ohio Oil August 1, 1921, the year following his graduation from International College, School of Commerce, Fort Wayne, Ind. His first position was that of clerk in the Haynesville, La., field office. Later he was transferred to the division office at Shreveport, where he was advanced to assistant division comptroller on January 1, 1925.

On September 17, 1928, Hardwick was transferred to Robinson, Ill., where he was placed in charge of the company's refining and marketing offices. Six years later, he was assigned to the general offices at Findlay as assistant manager of the refinery and marketing department.

Hardwick is active in American Petroleum Institute, serving on its board of councillors and as a member of the committee on highways.

J. R. Nichols has been made superintendent of Humble Oil & Refining Co.'s gas plant at Conroe, Tex., to succeed **J. A. Lee,** who resigned to enter private business. Nichols was transferred from Luling, Tex. **I. C. Corbell,** gas-plant superintendent at the Tomball, Tex., gasoline plant, has been transferred to the Flour Bluff, Tex., plant in a similar capacity. **W. A. Drake,** superintendent at the Flour Bluff gasoline plant, has been transferred to the Tomball plant. **M. A. Jills** has been transferred from the Katy, Tex., gas plant to the Hilbig, Tex., gas-repressuring plant in the Luling, Tex., district as repressuring-plant foreman.

Raymond R. Hooper, until recently assistant director of supply and transportation for District 1, Petroleum Administration for War, has been appointed traffice manager of Cities Service Oil Co. (Pa.)

Capt. Robert S. Christie, who served in the petroleum division during the war, has rejoined Amerada Petroleum Corp. at Fort Worth as division petroleum engineer for West Texas and New Mexico.

Scott Hughes, Dallas, has been elected vice president of Southern Union Gas Co., and **Willis L. Lea, Jr.,** Dallas, general attorney. Hughes, formerly general attorney and for the past 3 years on leave of absence as a major in the Army Air Corps, was released from active duty recently. Lea, a member of the legal department since 1936, is assistant secretary of the company.

SCOTT HUGHES

W. L. LEA, JR.

Edward V. O'Rourke, professor of petroleum engineering at Ohio State University, has been appointed director of Marietta College's new Edwy R. Brown School of Petroleum. Endowed by the will of the late Edwy R. Brown, Marietta alumnus and widely known oil man of the southwest, the school trains young men for careers in the oil industry. O'Rourke, an Ohio State graduate in mining engineering, has had experience scouting in oil fields of West Virginia, engineering in Chile, sampling and assaying in Nevada, field exploration in Venezuela, consulting engineer in Columbus, Ohio, and 20 years of teaching at Ohio State. He has been associated with Gulf Oil Corp., Maracaibo Oil Exploration Corp. and Phillips Petroleum Co.

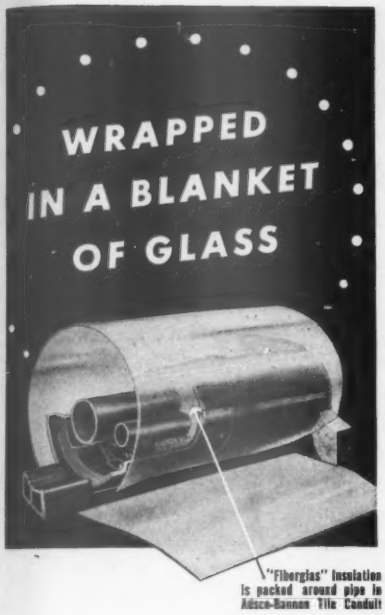
P. L. HOWARD

Porter L. Howard has returned from government service to his job as general traffic manager of Sun Oil Co., but remains on call to advise **Col. J. Monroe Johnson,** director of Office of Defense Transportation, on special problems. One such problem resulted from the oil strike, which took him back to Washington for 2 weeks. It was the third time Howard had left and then returned to ODT. He is described by Col. Johnson as "one of the few transportation men in the oil industry who have had practical experience with all of the forms of petroleum transportation."

J. Norvelle Walker, vice president and controller of Royal Oil & Gas Corp., has been chosen vice president of the Philadelphia Control. Controllers Institute of America. **Robert G. Dunlop,** controller of Sun Oil Co., was reelected a director.

Lewis F. Scherer, formerly assistant chief engineer of The Texas Pipe Line Co., has been made chief engineer. Scherer was superintendent in charge of pump-station construction during the building of the big-inch and little big-inch lines of War Emergency Pipelines, Inc.

M. W. Ransom, formerly superintendent of the oil transportation department for Union Producing Co., Shreveport, and for years an independent oil operator, has been named district manager of new district offices which the company has opened in Tyler, Tex., and will supervise production operations in the



Steam Carried Long Distances with Minimum Heat Loss

For an efficient steam line installation, you will put the pipe underground where it is out of the way — give it the best protection against moisture that you can — insulate it to keep the heat in the line to the point of delivery.

That's just the combination you get when you run your steam lines in ADSCO-Bannon Tile Conduit. Made of vitrified clay tile, installed with ADSCO Filler Insulation (a "Fiberglas" Product) it can't be topped for permanency or thermal efficiency.

Furnished for several combinations of pipe in the same conduit. Split tile construction makes pipes readily accessible for threading or welding. Highly skilled labor not required.

Base drain carries away ground seepage water — keeps insulation dry — prevents undue heat loss. Write for quotation giving length of line and size of one or more pipes to be insulated and Bulletin No. 35-670.

AMERICAN DISTRICT STEAM COMPANY
NORTH TONAWANDA, N.Y.
MAKERS OF "UP-TO-DATE" STEAM LINE EQUIPMENT FOR OVER 65 YEARS.

Write for Quotation On

ADSCO-BANNON TILE CONDUIT
WITH ADSCO FILLER INSULATION
(A "Fiberglas" Product)

East Texas area, chiefly in the Carthage pool, Panola County. **M. C. Foster,** formerly assistant head of the department of contracts and right-of-way in the general offices, is district landman. **R. Q. Murph,** former geological scout for the company, is district geologist. He is a University of Texas graduate.

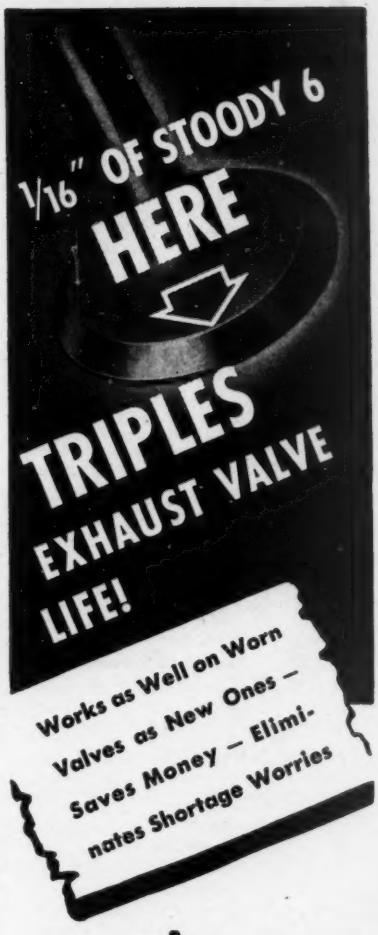
Col. Joseph A. Moller, of Chicago, has returned to The Pure Oil Co. after 44 months in the Army Air Corps and is located in the company's central control laboratory in Northfield, Ill. He commanded a heavy bombardment group of Flying Fortresses in the Eighth Air Force, and his group holds the record for number of enemy aircraft shot down in a single engagement.

GAGE LUND

Gage Lund, president of The California Co., with headquarters in New Orleans, has been made chairman of the board of directors of that company and of Standard Oil Co. of Texas, both subsidiaries of Standard Oil Co. of California. His office will be in San Francisco. Lund is succeeded as president of The California Co. by **K. H. Crandall,** who has been vice president and director since the company began active drilling operations in Mississippi and Louisiana.

LEGAL

UNITED STATES DEPARTMENT OF AGRICULTURE, Forest Service, Jackson, Mississippi, November 6, 1945. Sealed bids in duplicate will be received until 10:00 A. M. Central Time, December 7, 1945, and then publicly opened, offering bonus for operating rights in connection with gas and oil leases on a block of national forest land which is divided into three parcels, located in Scott County, Mississippi. The block contains Parcels A of approximately 606.56 acres, more or less, in Township 7 North, Range 7 East, Section 22, S½; Section 23, S½ S½; and Section 26, N½ NE¼; and NE¼ NW¼. Parcel B of approximately 540.09 acres, more or less, in Township 7 North, Range 7 East, Section 26, E½ SE¼; SW¼ SE¼; SW¼ SW¼; Section 34, S½ SE¼; and Section 35, E½ NE¼; N½ NW¼; SW¼ NW¼; and W½ SW¼. Parcel C of approximately 735.17 acres, more or less, in Township 7 North, Range 7 East, Section 27, W½; NW¼ NE¼; N½ SE¼ NE¼; N½ SW¼ NE¼; SW¼ SE¼; SW¼ SW¼ NE¼; West 30 acres of NW¼ SE¼; Section 34, W½ NW¼; and SW¼. Bids may be submitted for the entire block or separately for any or all parcels thereof, or in both ways. If the aggregate of the several high bids on the individual parcels of the block exceeds the maximum bid for the block as an entirety the bids on the parcels will be accepted. If, however, a bid on the block as an entirety is higher than the aggregate of high bids on the several parcels thereof, then the bid on the entire block will be accepted. Award of lease will be made only to bidder who can show sufficient experience and financial resources and prove citizenship. Interested parties may obtain bid documents, lease forms and operating regulations from the Forest Supervisor, Masonic Building, U. S. Forest Service, Jackson 114, Mississippi.


1/16" OF STOODY 6
HERE
TRIPLES
EXHAUST VALVE
LIFE!
Works as Well on Worn Valves as New Ones — Saves Money — Eliminates Shortage Worries

AN ounce or two of Stoody 6 welded to new or worn exhaust valve faces adds 300 to 400 percent to their normal life, prevents burning, saves overhaul jobs, costs only a few cents per valve.

This folder outlines the simple procedure any garage or shop equipped with acetylene welding equipment can follow. Eliminates your worries about valve replacements and saves money as well.

Write for folder "Weld New Life Onto Worn Valves With Stoody 6" — no obligation.

STOODY COMPANY
1138 SLAUSON AVE., WHITTIER, CALIF.

STOODY 6-*THE METAL THAT ADDS EXTRA MILES TO EXHAUST VALVE LIFE!*

W. F. BONNER

J. G. HULL

R. M. DARR

LYNN SAWYER

VAN DER BOOM

D. H. HYLER

Equipment Men in News

Randolph C. Walker, president and general manager of Aireon Manufacturing Corp., has announced the appointment of **William F. Bonner** as general manager of Midco Tool & Supply Co. of Oklahoma City, a subsidiary of Aireon. Bonner comes to his new assignment with a substantial background, both in previous connections and in the Burbank Hydraulics division of Aireon where, since 1942, he was first contract administrator during the heavy war period, and later sales manager for that division.

Cummins Engine Co., Inc., Columbus, Ind., has announced the appointment of **James G. Hull** as manager of the Fort Worth region, with offices at 1812 Fair Building, Fort Worth, Tex. He succeeds **Jay B. Chambers**, who resigned recently to purchase the Denver dealer franchise for Cummins engines.

Appointment of **Robert M. Darr** as advertising manager of Le Roi Co. and Centaur Co. has been announced by **John Dolan**, manager of the sales division.

Lynn Sawyer, general manager of the pump division of Byron Jackson Co., has been elected a vice president, according to **E. S. Dulin**, president.

G. L. Van der Boom, formerly advertising manager of Southwest Welding & Manufacturing Co., Alhambra, Calif., has joined Russell P. Ostrander, Advertising, in the capacity of account executive.

D. H. (Friday) Hyler has joined the sales staff of the Republic Supply Co. with headquarters at the general offices in Houston. His work will be in connection with refinery and industrial sales. **H. T. Hopkins** has been appointed assistant district manager for Republic Supply Co. at Kilgore, succeeding **Tom C. Hendricks**, who has been transferred to Wichita Falls as district manager. Hopkins will continue to make his headquarters at Kilgore but will serve as assistant to **J. B. Lionberger**, district manager at Shreveport, and will cover the territory included in that district west of the Mississippi River.

Wagner Electric Corp. announces that **J. D. Eby**, manager of purchases, has been elected secretary of the company, filling the vacancy created by the death of J. W. Westcott.

Robert M. Hatfield has resigned as deputy vice chairman of War Production Board to become assistant general sales manager of Combustion Engineering Co.

R. P. Tyler has been elected to fill a vacancy on the board of directors of Macwhyte Co. caused by the resignation of **Mrs. George S. Whyte**. Tyler is also general sales manager of the company.

American Chain & Cable Co., Inc., Bridgeport, Conn., has acquired the business of Certified Gauge & Instrument Corp., of Long Island City, N. Y. Manufacturing will continue at the Long Island City plant under the name Helicoid Gage Division, American Chain & Cable Co., Inc.

For the third consecutive year, Chain Belt Co., Milwaukee, Wis., has received an award of merit for excellence in reporting its financial and business activities to the stockholders. The company's 1944 annual report was recently awarded "best in the industry" at Financial World's annual report awards dinner in New York. An "Oscar" commemorating this event was presented to the firm's president, **J. C. Merwin**. The book was designed by **G. H. Pfeifer**, advertising manager of Chain Belt Co.

Appointment of The Straker Supply, Mount Pleasant, Mich., as distributor for Bucyrus-Erie oil-well spudders, is announced by Bucyrus-Erie Co., South Milwaukee, Wis.

Edward A. Reineck has joined the technical sales staff of the chemicals department of The Quaker Oats Co., Chicago, Ill. He will assist in the development of new applications for furfural and its derivatives in the resins and plastics industry.

Kenneth D. Halleck, Washington sales representative the past 2 years for Aireon Manufacturing Corp., has been named to fill a vacancy on the corporation's board of directors. He will be moved to the company's headquarters in Kansas City as administrative assistant to **A. E. Welch**, executive vice president.

All employes of Geo. E. Failing Supply Co., Enid, Okla., and Houston, Tex., are receiving a pleasant surprise on their return to company employment after being discharged from the armed forces. They are called to the office of **Robert Greer**, treasurer and purchasing agent, and handed a package of war bonds which had been purchased for them by the company during the time they were in service. The policy of buying a bond a month for all Failing employes in the service was instituted in June 1943, and every month since then a bond has been bought for each employe of the company who had been employed for as long as 1 year previous to going into service. A total of 777 bonds, with a maturity value of $19,425, already has been purchased. Twenty-five men are participating. Up to date bonds have been delivered to six of the former Failing workers who have been released from the army and the company will continue to buy a bond a month for the others until they, too, receive their service discharges. **Joel E. Yarborough**, member of the Failing engineering staff, received a total of $1,125 in bonds.

H. T. HOPKINS

J. D. EBY

R. M. HATFIELD

George E. Failing, Robert Greer, and Capt. J. E. Yarborough